EAST AFRICA HIGH COMMISSION

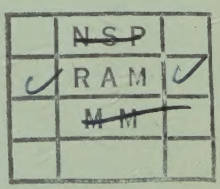
EAST AFRICAN AGRICULTURE
AND
FORESTRY RESEARCH ORGANIZATION

RECORD OF RESEARCH

for the period

1st July, 1956 to 31st December, 1957

ANNUAL REPORT, 1957



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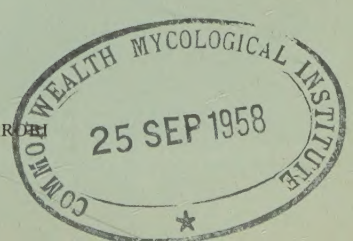

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STUDY OF PLANT PARASITIC NEMATODES :

A. G. Whitehead, B.SC., A.R.C.S. . . . . *Entomologist*

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PREFACE

The East African Agriculture and Forestry Research Organization (E.A.A.F.R.O.) is an interterritorial research organization administered by and forming part of the East Africa High Commission. It was set up in 1948 and absorbed the earlier East African Agricultural Research Institute at Amani, Tanganyika, which was started in 1927. E.A.A.F.R.O. is financed jointly by the three East African Territories of Kenya, Tanganyika and Uganda, by the Protectorate of Zanzibar, and by the United Kingdom Government through Colonial Development and Welfare Funds. Its headquarters and central laboratories, experimental farm and forest plantations are in Muguga Forest near Nairobi on the site generously given by the Government of Kenya.

E.A.A.F.R.O. works very closely with the corresponding organization for veterinary research, the East African Veterinary Research Organization (E.A.V.R.O.). The two organizations have a common headquarters at Muguga, and the two sets of laboratories and farms are on adjoining estates each excised from the Muguga Forest. They are jointly responsible for the Library, which is the largest and most complete library for agriculture and the agricultural and ancillary sciences in East Africa. In addition, research work on animal husbandry is shared out between them. It was originally carried out by the Joint Animal Industry Division under Dr. M. H. French, a Deputy Director, and it was a joint responsibility of the two Directors. With Dr. French's retirement in 1956 it was agreed that this joint Division be divided into two: an Animal Nutrition Division under the Director, E.A.A.F.R.O. and an Animal Production Division, dealing with animal breeding, physiology, and biochemistry under the Director, E.A.V.R.O. Muguga South Farm, which was used by the Joint Division, is still being used by the two Divisions, though it is managed by the Director, E.A.A.F.R.O. Thus this Report only contains the work on animal nutrition and not as heretofore of all the work on animal husbandry.

The general policy, both for E.A.A.F.R.O. and for E.A.V.R.O., is decided by the East African Agricultural and Fisheries Research Council, a Council whose members are nominated by the Territorial Governments, the High Commission and the Colonial Office, and this Council is also responsible for the general running of both the Organizations.

The principal functions of E.A.A.F.R.O. are to undertake research work that is either longer-termed than is easily undertaken by the Territorial Departments of Agriculture and Forestry, or is common to all or several of the Territories, or which requires highly specialized equipment or research officers, which can only be justified in a central East African laboratory. Examples of each of these types of work will be found in the body of this Report. E.A.A.F.R.O., however, is only concerned with problems of local interest when specially invited by a Territorial Department. Its function is therefore to supplement and supply the background to the work of the territorial research workers.

The planning of the detailed research policy of E.A.A.F.R.O. must obviously be done in very close co-operation with the Territorial Departments, and this is ensured with the Agriculture, Animal Industry and Forestry Research Co-ordinating Committees set up by the Research Council under a High Commission Chairman, which are composed of the Territorial Directors of Agriculture and the Veterinary Services, and the Chief Conservators, the Director, E.A.A.F.R.O., and for the Animal Industry Committee of the Director, E.A.V.R.O. These Committees, in conjunction with the Research Council, keep under review all the research work in progress and decide on general priorities for research, particularly the longer-term or more specialized research that is the direct concern of E.A.A.F.R.O.

E.A.A.F.R.O. is also directly concerned with a further set of Committees, the Specialist Committees, which are composed of the actual specialist research workers in East Africa in each of the disciplines represented. These Committees are therefore competent to discuss the technical problems with which the research workers are faced in carrying out their work, and to make detailed proposals for new work or for an extension of current work.

It was decided at the 3rd Meeting of the Research Council held on 3rd February, 1955, that in future the Annual Reports of E.A.A.F.R.O. should be published in two parts; one part, which is contained in the Annual Report of the Research Council itself, is intended to tell the non-scientist of the work and achievements of E.A.A.F.R.O. in the year under review; the other part, which is this Report, is written more for the information of research workers, particularly in other parts of the world.

INTRODUCTION

VISITORS, STAFF AND REORGANIZATION

1. *Visitors.* This Organization was honoured on 11th October, 1957, by a visit from the Secretary of State for Colonial Affairs, the Rt. Hon. Mr. Alan Lennox-Boyd, who was accompanied by H.E. the Governor of Kenya, Sir Evelyn Baring, in his capacity as Chairman of the E.A. High Commission. The party had an opportunity of seeing something of the scope of the work of this Organization and of learning how many of the results obtained here applied directly to a large area of the tropics, although the actual problems being worked on are chosen because of their practical importance to East Africa.

2. *Staff Changes.* One new Research Officer joined the staff at Muguga in November, 1956, Dr. M. Dagg of the Physics Division, and three have left, Mr. J. C. M. Gardner the Forest Entomologist who left on retirement leave in April, 1957, Dr. P. R. Hesse, Soil Chemist and Mr. D. L. Jennings, Plant Breeder, who left on transfer in June and October, 1957. In addition, Mr. L. C. Martin, the Maintenance Superintendent, left in May, 1957, on retirement leave. He was the first member of E.A.A.F.R.O. staff to live at Muguga, he supervised the construction or was responsible for all the buildings on the E.A.A.F.R.O. estate, and has given the station sterling service for the first eight years of its existence. His place has been taken by Mr. J. B. Drummond, who has come to us from the E.A. Railways and Harbours Administration.

3. This year, for the first time, a University Research Student has been working at E.A.A.F.R.O. Miss J. M. Kenworthy of the Department of Geography, Oxford, was awarded a Leverhulme Fellowship to work for her B.Litt. in East Africa, and has been attached to the Department of Geography, Makerere College. By arrangement with Professor S. J. K. Baker she has spent much of her time working under Mr. J. Glover, our Plant Physiologist, on some problems of the East African climate of importance in agriculture.

4. Two schemes, financed entirely out of C.D. & W. funds, have been attached to E.A.A.F.R.O. The Survey of Insect Pests of Cereal Crops under Dr. I. W. B. Nye, has continued throughout the period under review, and the Survey of Plant Parasitic Nematodes under Mr. A. G. Whitehead began in August, 1956.

5. *The Animal Nutrition Division.* At the Seventh Meeting of the E.A. Agricultural and Fisheries Research Council it was agreed that the Joint Animal Industry Division, which was jointly administered by the Directors of E.A.A.F.R.O. and E.A.V.R.O., and was concerned with all work on animal husbandry, should be broken up into two Divisions, Animal Nutrition including all pasture work to become part of E.A.A.F.R.O., and Animal Production dealing with animal breeding, animal physiology, and biochemistry to become part of E.A.V.R.O. This reorganization was consequent upon the retirement of Dr. M. H. French who was Head of the Joint Division with the standing of a Deputy Director. As a consequence of this reorganization the old A.I.D. Farm becomes the Muguga South Farm, but is still designed to serve both Divisions as far as possible, though it comes under the responsibility of the Director, E.A.A.F.R.O. Although this Joint Division has been disbanded, it is planned to maintain very close collaboration between the two Divisions.

THE PROGRESS OF RESEARCH

6. At the outset of this Report I want to take this opportunity of emphasizing that since E.A.A.F.R.O. is an interterritorial station, a very great deal of the work described here could only have been done with the very ready and active co-operation of many research and administrative officers in the Territories. It is a great pleasure to acknowledge the help they have given us and to thank them all for it.

7. The work of the Physics Division and the Plant Physiologist continues to be concentrated on studying the water relationships of plants and soils, and in particular with problems concerned with making the very best use of the water available, particularly in areas where water is limited. Four very ambitious catchment-area experiments are to be carried out in East Africa jointly by the Physics Division and various Government Departments in the Territories, in which the Forestry Departments will be taking a major share. Three of these have now been properly begun, and the fourth is in its initial stages of starting. Dr. Pereira was able to visit the U.S.A. this year to discuss with their catchment research workers, hydrologists, physicists and others, some of the problems of running experiments of this type, and of extracting in the most economical way the information required from the great mass of data which have accumulated.

8. Another important aspect of their work is concerned with the calculation of the amount of water crops are using week by week from simple meteorological and basic soil data, and comparing this with the amount determined by direct soil sampling. A trial of a method now proposed over a six-year period with Arabica coffee on a deep soil has shown that throughout this period the calculated moisture content in the soil agreed with that found by periodic direct determinations within the limits of accuracy of the sampling. The most important meteorological measurement for this calculation is the amount of solar energy reaching the earth surface day by day. A simple instrument for measuring this has been under test for several years, and it appears to be so satisfactory that it has now gone into commercial production. Several of the first batch have been tested here and it is hoped that a considerable number will soon be in use in East Africa.

9. The Plant Physiologist has been particularly concerned with the effect of drought on maize and sorghum leaves, and he has found that if a maize becomes badly wilted it will regain turgor after the soil is re-wetted, but the stomata have been permanently injured so that the photosynthetic ability of the leaf drops to a low level. On the other hand, when a badly wilted sorghum leaf regains turgor the stomata continue to function fairly normally. Thus maize yields can be severely depressed by late drought, although a plant may look quite healthy, whilst sorghum yields are much less sensitive.

10. The two important aspects of the work of the Chemistry Division concern the prediction of crop responses to phosphate fertilizers from the chemical analysis of the soil, and the build-up of nitrates in the soil due to the decomposition of soil humus. The Department of Agriculture, Kenya, has been running a number of phosphate trials in the field with various crops and on different soils, and this Division has been given the opportunity for carrying out chemical analyses on the soil and plant samples. None of the standard chemical methods of soil analysis has been found to be of any value for predicting the responsiveness of crops to phosphate fertilizers on these soils. However, an incidental result of great interest which has come out of this work is that adding a phosphorus fertilizer to a soil has increased the plant available P in that soil for a number of years, and no soil has yet been found which locks up the phosphate of the phosphate fertilizer in an unavailable form.

11. The work on the factors responsible for the oxidation of soil organic matter or soil humus, and the production of soil nitrates therefrom, has now shown quite definitely that the soil humus can be divided into two parts. One part of it is held by the soil and is resistant to decomposition, even if the soil is kept moist, warm and well aerated; and one other much smaller part is in the soil solution and oxidizes rapidly under these conditions. Humus only comes into solution when a dry soil is wetted, and the drier the soil before wetting the greater the amount of organic matter coming into solution. Thus nitrates are only produced in the soil in appreciable amounts during the first rains after the dry season, and during the rains these nitrates are liable to be washed out without any appreciable production of new nitrates later on. This explains a common finding in East Africa that late-sown crops never give the yield of early crops, even if water and diseases are not limiting, and it emphasizes the need to get these crops established as early as possible so that the roots have the maximum chance of picking up as much as possible of the nitrate produced in this early flush of decomposition.

12. The Plant Pathology Division has brought to a completion a very successful piece of work on breeding maizes resistant to tropical American Maize Rust, *Puccinia polysora*, which reached West Africa in 1949 and East Africa in 1952. Maizes resistant to it were looked for and were found amongst a number of Central American maize varieties. It was shown that these carried one of two genes for resistance (which later work allowed to be linked and hence to occur on the same chromosome). Methods for testing resistance of seedlings to the rust were developed, and breeding material containing one or other of these genes were sent out to the Departmental plant breeders so that they could transfer this gene to their local varieties. Seedlings from their progenies were grown by the plant breeders and also at Muguga, and the lines homozygous for resistance were identified and only these were grown by the plant breeders and back-crossed to the local material. In this way it was possible from Central American seed imported into Muguga in 1953, to be able to plant in 1957 a considerable acreage in the Southern Province of Tanganyika of high-yielding local varieties having this resistance incorporated in them. A study has now begun on genetics of the resistance some Peruvian maizes possess to Streak, a virus disease of maize carried by the leaf hopper *Cicadulina mbila*, and which depresses the yield of maize seriously in several districts of East Africa.

13. The Silvicultural work is also largely devoted to forest problems in the drier areas of East Africa. It is concerned on the one hand with nursery management and the care of young seedlings when planted out in the forest, and on the other with the testing of a large number of mainly exotic trees in the Muguga Arboretum for their suitability for production of firewood, housing material or timber. The general principles of nursery and transplanting management have now probably been found, the principal experimental results have been written up, and courses of instructions to foresters and African nursery headmen held both at Muguga and at the actual forest nurseries themselves. The Forest Entomologist, Mr. Gardner, retired in March, 1957, but before he left he prepared a list of East African forest insects which was based on a survey of forest insects carried out during the last seven years under his supervision. Over 30 per cent of the species found are not in the British Museum, and most of these have not yet been properly named or described by taxonomic specialists. This increasing number of new species which cannot be named by the Commonwealth Institute of Entomology will become increasingly embarrassing as more detailed work on the control of forest pests becomes possible.

WORK ON OUTSIDE COMMITTEES

14. The Director is a member of the E.A. Agricultural, Animal Industry, Forestry, and Tsetse and Trypanosomiasis Research Co-ordinating Committees, and Chairman of the Soil Fertility and the Pasture Research Specialist Committees. He organized and was Chairman of the first E.A. Weed Control Conference held at Muguga in January, 1957. He is a member of the Kenya Agricultural and Veterinary Research Advisory Committee, the Kenya Pasture Research Committee, Chairman of the Research Committee of the Tanganyika Coffee Growers Association, a member of the Research Committee of the Tanganyika Sisal Growers Association, of the Governing Body of the Tea Research Institute of East Africa, and of the Namulonge Advisory Board of the Empire Cotton Growing Corporation. He is a member of the Scientific Council for Africa South of the Sahara (C.S.A.), and attended its 8th Meeting in Salisbury in August, and was able to visit Nyasaland at the invitation of the Director of Agriculture, and some of the Federal Research Stations, and to discuss with them some research problems of common interest to them and

to East Africa. He attended by invitation a Conference on Soil Conservation in Arid and Semi-Arid Regions sponsored by the Pakistan Agricultural Council and the Arid Zones Committee of U.N.E.S.C.O. at Karachi in November.

15. Dr. H. H. Storey is a member of the E.A. Medical Research Council and the E.A. Industrial Research Board, a Trustee of the Coryndon Museum, and Chairman of the E.A. Standing Technical Committee on Plant Import and Export, of which Mr. P. J. Dickinson is Secretary. Dr. A. L. Griffith is a member of the E.A. Timber Advisory Board and is Chairman of the Silvicultural Specialist Committee. He attended the Seventh British Commonwealth Forestry Conference in Australia and New Zealand in August, 1957. Mr. J. Glover is a member of the Kenya Pyrethrum Technical Consultative Committee, and Dr. H. F. Birch is a member of the Kenya Wheat Baking Quality Committee. Mr. H. P. Ledger attended by invitation meetings of the Kenya Pasture Research Committee and the Kenya Pig Industry Board.

WATER AND CROP GROWTH

CATCHMENT AREA RESEARCH

H. C. Pereira, J. S. G. McCulloch, M. Dagg, P. H. Hosegood, J. W. Simmons, E. Kasavuli and S. Ngethe

16. The Physics Division has, as its main responsibility, the study of the effects of land-use changes on the water yields of catchments. All members of the Division are taking part in this research and the first priority throughout this 18 months' period has been to assist the Kenya, Uganda and Tanganyika Governments in the construction and installation phases of their four large-scale catchment research experiments as outlined in the Annual Report for 1956. These involve a dozen technical departments in addition to officers of the Provincial Administrations. These experiments are widely scattered throughout East Africa and by the nature of the problem are not all easily accessible, so that assistance with their development has involved a strenuous programme for the Division. This form of co-operative work has been welcomed in all Territories, and it is pleasant to record the enthusiastic co-operation of the three Forestry Departments. The Geological Departments contributed valuable advice in the planning stages and subsequently inspected the sites of the experiments. The Departments for Water Engineering in all three Territories, although short of staff and heavily committed, have nevertheless been good enough to undertake construction of weirs in valleys difficult of access and have thus made possible the commencement of this research. The Agricultural Departments assisted in planning and are helping with supervision, while the Provincial Administrations have given essential support to these experiments, two of which will be of direct help to them in elucidating land-use problems in tribal administration.

17. The Resident African staffs, administered by the Forestry Departments, have been trained for three of the experiments and are already producing useful data.

18. These catchment studies are raising interesting problems in meteorological recording such as the gauging of rainfall at the top of high forest canopies. Full meteorological information is being collected at all sites, and used to estimate evaporation losses as part of the water balance. The main constructional and installa-

tion work is now complete on all of the 11 valleys under study, and on nine of these full recording of rainfall and river flow is now under way.

19. *Methods of Hydrological Analysis.* The hydrological problems of land use on which the East African Governments most urgently need quantitative investigations are unfortunately too pressing to permit the use of those classical methods of study in which the streamflow behaviour of each valley is measured for some 10 to 20 years before the land-use change is applied. The land-use changes are actually taking place and an entirely different method of approach is essential. The method on which the East African experiments are based has been evolved over the past ten years of detailed research into water use of different plant covers. Gypsum blocks are used to depths of 10 or 15 feet to indicate the soil moisture tension distributions throughout the root range, and thus to isolate periods in which losses by drainage are negligible. Extensive and deep soil moisture samplings over these periods give quantitative estimates of evapotranspiration. These are related to the continuously-recorded radiation and evaporation data taken within these areas in order to obtain continuous estimates of evapotranspiration; volumetric tests on core samples throughout the root ranges give the wilting and field capacity limits and thus permit the calculation of a water balance for each type of cover. A six-year analysis of the water-use of coffee, outlined under the report on irrigation studies, illustrates the essentials of the method. In this way the changes observed in streamflow response to rainfall following the major experimental change in land use will be checked against the independent estimates of water loss by evapotranspiration and drainage.

20. Financial support from both the Colonial Office C.D. & W. funds and the East Africa High Commission enabled Dr. Pereira to spend three months of his overseas leave in a tour of the leading laboratories and field stations at which land-use hydrology is studied in the U.S.A.

21. East Africa data illustrating the above methods were discussed with leading research workers (foresters, physicists, engineers, geologists and mathematicians) engaged in hydrological experiments. Many expressed the opinion that the deep soils and the marked wet and dry seasons characteristic of East African catchment areas together with the large-scale experimental land use changes involved, offered unusually favourable prospects for

success in these studies. A great deal of valuable technical information was obtained and a report on this is in preparation.

RAINFALL MEASUREMENT

J. S. G. McCulloch

22. In the 18 months under review, networks of rain-gauges have been installed in all four catchment areas already described. It has also been possible to make a preliminary survey of the variation of rainfall over the catchments at Fort Essex in the Aberdares and at Mbeya Range in Tanganyika. It appears probable that due mainly to the low wind speeds generally obtaining at equatorial latitudes, a reasonable estimate of mean rainfall over a small catchment may be obtained by averaging the results of a network of gauges which has been sited with due consideration for the different slopes and aspects of a catchment. To avoid extensive rain-gauge clearings in the control catchments at Fort Essex, gauges have been mounted at the level of the bamboo canopy by lopping off suitable Podocarpus, and building platforms 40 to 60 feet above the ground. This followed experimental work at Muguga, when it was found possible to use a standard rain-gauge funnel mounted on the platform, with a $\frac{1}{4}$ in. P.V.C. tube to lead the rain down to a collecting bottle on the ground below. This avoids the necessity for the observers climbing the trees daily.

23. At each catchment experiment a meteorological site has been installed and routine climatological observations of air temperature and humidity are taken twice daily, in addition to wind run at 6 feet above ground, hours of sunshine, radiation, rainfall and tank evaporation. Setting up of these sites and checking, processing and analysis of the resulting data have been the responsibility of this section.

SOLAR RADIATION

J. Glover and J. S. G. McCulloch

24. With the development of studies of the physics of evaporation and transpiration it is essential to estimate the amount of solar energy received at various places on the earth's surface. The apparatus for reasonably accurate measurement of insolation is expensive and, as arranged for continuous recording, is not easily

portable. As a result our knowledge of the energy supply in underdeveloped areas is slight or non-existent. Even though the simple liquid distillation instrument described below under "Irrigation Investigations" offers an inexpensive device which can give very useful estimates of daily totals of radiation (except on very dull days) there cannot be complete coverage of the Territories. Amelioration of this situation may be possible if use is made of the existing records of hours of bright sunshine which are kept at many second order and even some third order meteorological stations.

25. Some years ago Angstrom pointed out that there was an empirical relationship between insolation and hours of bright sunshine and others have shown that this relationship varies from place to place on the earth so that a new equation must be used in each new area. In the hope of overcoming this restriction, data from many parts of the world have been examined and it has been found that there is an underlying uniformity which indicates a more general usefulness. Indeed, in our most recent work it has been possible to show that there is a simple general relationship which provides reasonable estimates of radiation Q from hours of bright sunshine n by means of the equation $Q = Q_A (0.29 \cos \varphi + 0.52\ n/N)$ where Q_A is the amount of radiation falling on a horizontal surface at the outer limit of atmosphere at latitude φ and N is the total possible hours of bright sunshine at the same latitude. This expression seems to be effective from 0° to 60° latitude which includes most of the inhabited portion of the globe.

26. Radiation as measured by the Kipp-Moll instrument at Muguga is included in the table of meteorological values for 1957.

IRRIGATION INVESTIGATIONS

H. C. Pereira, J. S. G. McCulloch, M. Dagg, P. H. Hosegood and J. W. Simmons

27. A six-year study of the water use of unshaded arabica coffee was completed and prepared for publication by Dr. Pereira and appeared in the *Journal of Agricultural Science*. The method

of water-use estimation evolved in this study was to relate quantitative soil moisture changes in 10 feet of soil as obtained by direct soil sampling to the daily evaporation from a sunken open pan. The resulting simple water-use estimation from open pan evaporation is being applied by the staff of the Coffee Research Station, Ruiru, and is available as an advisory service to all plantations equipped to measure the amounts of irrigation water applied to their coffee.

28. These studies have shown the suitability of the simple Gunn, Kirk and Waterhouse distillation device for estimation of radiation and hence of water use. Integrating incoming sun energy by the evaporating of water in a closed system, this simple device is particularly suitable for water-use studies in the semi-arid tropics, where open tanks are difficult to operate. As described in the two previous Annual Reports of this Division, the earlier performance of the prototype instrument led to arrangements for manufacture of this device. Calibration of the first batch of manufactured instruments at Muguga against the Kipp-Moll standard solarimeter has given remarkably good results. Correlation between total daily radiation and the daily distillation of water has given values for r^2 of 0.93 for the prototype, 0.95 for a simplified and robust form, and 0.97 for each of three instruments equipped with improved condensers. They need, of course, individual direct callibration by comparison with a standard instrument. In the Perkerra Irrigation scheme, where water supplies are critically short, this device is being compared with tensiometers and with electrical resistance units for soil moisture measurements, to help improve the water economy of the scheme.

29. The Division has continued to help both the Kenya Department of Agriculture and Tanganyika Agricultural Corporation (F.A.O. Rufiji Basin Survey) by core-sampling of soils for the measurement of water storage and infiltration rates, and also in the assessment of water requirements for irrigation. In co-operation with Mr. Anderson, Soil Surveyor of the T.A.C., core-sampling has been carried out on the 5,000-acre pilot scheme on the Bohoro Flats. Similarly, soils at Lodwar, in Kenya's Northern Frontier Province, have been core-sampled and studied for irrigation properties.

SOIL SCIENCE AND TILTH TESTING

M. Dagg

30. The Division was joined in September, 1956, by Dr. Dagg who took over the work on soil structure and tilth testing.

31. In co-operation with the East African Tractor and Implement Testing Unit, an investigation was made into the uniformity of soil properties over the field used for the assessment of tractor drawbar pull. Total pore space and moisture content measurements of surface soil cores were made in conjunction with measurements of soil shear strength at a depth of two inches. No significant variations over the field were found.

32. A long-term manurial trial laid down in 1936 at the Uganda Department of Agriculture Experiment Station, Serere, was examined for improvements in physical properties of the soil. Assessment of soil stability by a wet sieving technique in 1944 has suggested that the manurial treatments had conferred no beneficial effects. However, the results in 1957 showed that rainfall acceptance rates were more than 100 per cent better on manured plots than on those unmanured. The soil cores from the manured plots also showed a significant increase in total pore space when compared with the control plots.

33. Infiltration tests are in progress on the 3,000 acres of semi-arid grazing land in the catchment area studies of grazing control in Karamoja, using the rainfall test on soil cores described in the previous Annual Report. The crop rotation and terrace-effect experiments at Muguga have now produced a range of soil structural conditions whose practical agricultural effect is measurable as run-off, and thus provide a "test-bed" for infiltration techniques and methods of soil structure assessment, as well as yielding useful data on crop water-use and the effects of terraces.

34. Simple pressure plate equipment has been assembled to examine the resistance-moisture tension characteristics of two types of electrical resistance units up to tensions of two atmospheres. The results show that the resistance of these units begins increasing between two-thirds and one atmosphere and therefore gives a reliable indication of the cessation of free drainage in a soil. A more elaborate pressure membrane equipment for the determination of soil wilting points is being constructed.

WATER CONSERVATION IN AGRICULTURAL ROTATIONS

H. C. Pereira and P. H. Hosegood

35. A four-year co-operative investigation, with the Tanganyika Agricultural Corporation, of the possibilities of water storage by fallows to improve the reliability of cropping, was completed and accepted for publication by the *Empire Journal of Experimental Agriculture*. This showed that, while water can be stored by bare-fallows, the soil deterioration under the severe climatic conditions of the semi-arid tropics can be prevented by a very heavy sowing of a shallow-rooted quick-growing annual grass (Teff-*Eragrostis abbysinica*).

36. On the rotation experiments at Muguga the outstanding effect has been the severe reduction caused by the trampling of cattle in the rates of acceptance and infiltration of rain-water. On 14 per cent slopes with a complete cover of three-year old star grass (*Cynodon dactylon*) terrace ditches were filled with rain-water, clean but nevertheless lost to the fields, after heavy grazing. The need to control grazing and to graze more lightly, leaving much more grass cover on East African pastures than on temperate zone pastures, has become apparent in two other related experiments.

LAND-USE EFFECTS FOR CLIMATE AND WATER RESOURCES

37. Dr. Pereira took part in four inter-departmental reconnaissances to advise on the physical aspects of particular land-use problems. The first two concerned the South Ankole Forest Reserve in Uganda, and the Mbozi Hills area in Southern Tanganyika. The third was to assist in the planning of research work for improvements in land-use in the Karamoja District of Uganda. After a reconnaissance of ecological zones with Mr. Trapnell, Dr. Pereira acted as Chairman for a group of 15 Uganda technical and administrative officers who drew up plans for agricultural and veterinary studies to improve land usage and the distribution of human and stock populations in the Karamoja District.

38. In the fourth study, on the Elton Plateau in the Southern Highlands Province of Tanganyika, Dr. Pereira and Dr. McCulloch joined the technical members of the Provincial team and together with the Chief Conservator of Forests examined problems of the protection of valuable catchment areas supplying water for the irrigation developments on the Bohoro Flats. An agreed set of recommendations was submitted to the Provincial Commissioner.

PLANT PHYSIOLOGY

J. Glover and M. Lampkin

39. *Some responses to drought in maize and sorghum.* As mentioned in last year's report a study of the stomatal behaviour of maize before, during and after drought, suggested that the inability of the stomata to recover from severe wilt might reduce the photosynthetic efficiency of the plant. This was investigated by means of simultaneous measurements of changes in stomatal aperture and carbon assimilation. The measurements of carbon assimilation served as a check on a stomatal behaviour as well as providing direct evidence of the photosynthetic activity of the leaf. As would be expected, there was a close correlation between stomatal aperture and rate of carbon assimilation, the correlation coefficient from 62 records being +0.86. Similar records were obtained for sorghum. In both maize and sorghum the stomata close as the plant wilts and there is complete or almost complete cessation of carbon assimilation.

40. *Maize.* If there is a mild drought, so that severe wilt lasts only one or two days and adequate water is then supplied to the plant, the leaves quickly retain turgidity, the stomata reopen and carbon assimilation continues normally, though there is a short delay between the apparently complete recovery of normal turgidity and the resumption of normal stomatal behaviour. The length of this period appears to depend on the duration of the wilt, the more severe the wilt the longer the period required for recovery.

41. If, however, the drought is severe and wilt persists for a week or more the consequences are more serious. If the drought is broken by the restoration of the soil water supply, the leaves do not recover completely even after a fortnight or more. They

regain turgidity within a few hours after watering but many of the stomata seem to be killed or severely damaged and do not reopen. As a result the intake of carbon dioxide is severely curtailed. All the leaves unfolded at the time of the drought are affected in this way, thus a plant which appears to have recovered from drought as shown by the apparently normal turgid leaves may in fact be an inefficient assimilator of carbon dioxide and yields may suffer.

42. The effect of severe drought at different stages of maturity of the plant was then examined. It was found that if severe drought affects a young plant, say at the four-leaf stage, these four leaves are markedly affected and carbon assimilation in them never recovers to normal levels when the drought is broken. On the other hand the leaves not yet unfolded are little affected for when they unfold their behaviour follows the normal pattern providing that they too, in turn, are not subjected to drought. Thus if severe drought hits a young plant and does not kill it completely some recovery is possible and yield may only be slightly affected. At the other extreme, if severe drought occurs at heading, when all leaves are unfolded, there is little chance of recovery when the drought is broken. The grain must be supplied from any reserve already present in the plant and from an extremely inefficient leaf system. In general terms it would seem that drought becomes progressively more dangerous to yield as the plant ages.

43. *Sorghum*. As with maize, a short wilting period has little effect on growth and yield. On the other hand, unlike maize, the stomata do not seem to close completely even during a severe drought lasting a fortnight or more. When the drought is broken the leaves recover much of their original efficiency after a short intermediate recovery stage lasting a day or two, and the plants though smaller are not so severely depressed as maize would be under similar conditions, although their yields are reduced. As with maize, drought of young plants is less harmful to yield than that of older plants but the differences are much less striking. It would seem that some of the well-known resistance to drought by this crop is due to the ability of the stomata to recover from severe water shortage.

44. The maize results have been confirmed in field plots. The sorghum results were obtained in greenhouse trials and have not yet been confirmed in the field.

RELIABILITY OF SEASONAL RAINFALL

J. Glover and Miss J. M. Kenworthy

45. Maps of the reliability of seasonal rainfall in Kenya will be published in a short time. The maps have been drawn for the reliability of 10, 15, 20 and 25 inches of rain falling in the long rains for those areas which have a definite long rains season.

46. In addition a beginning has been made on studying the effect of relief on rainfall, in particular the more detailed effects of slope, aspect and rain shadow. Where possible, these will be linked with the vegetation surveys conducted by the Ecology Section. As in past years, notes on the reliability of rainfall in different regions of East Africa have been supplied to various enquirers.

EFFECT OF ALTITUDE ON THE TEMPERATURE AND DEW POINT OF THE AIR

J. Glover and Miss J. M. Kenworthy

47. The behaviour of a plant is often much modified by temperature and the introduction of temperate zone crops into suitable rainfall areas of the high-altitude tropics is in large measure determined by this factor, although for some crops, sensitivity to length of day is also important. There is a commonly held view that an increase in altitude is directly comparable with an increase in latitude which would imply that temperate region crops could easily be grown in the high-altitude tropics such as the Kenya Highlands. This is only partly true, for the relatively constant length of the photo-period restricts some crops and the wide diurnal range of temperature in the high tropics affects others. Unlike the more temperate regions where long periods of cold in winter alternate with long periods of warmth in summer, the high tropics provide much of this temperature range in a single day and the duration of either chilling or warmth is relatively ephemeral. This too affects the response of introduced plants, particularly those which require chilling for flower-bud stimulation.

48. Temperature recording stations are very scanty in East Africa so no detailed study of the effect of altitude on air temperatures is yet possible. But an examination of the available data has shown that the mean annual temperature, the mean

annual dew point and the altitude of the recording station, are markedly related to one another, as might be expected, but the dependence of dew point on mean temperature is a spurious correlation derived from their common dependence on altitude. The following equations describe the prime relationships: —

Mean temperature (°F) = 82 − 0.0029 altitude (ft.) ($r^2 = 0.86$)

Dew point (°F) = 72 − 0.0029 altitude (ft.) ... ($r^2 = 0.85$)

These two temperatures are so closely related to altitude that regional difference due to other causes, such as the proximity to Lake Victoria, are relatively small.

49. From these two relationships arises the most interesting conclusion that *on the average* the mean temperature at any altitude is only some 10° F. above the dew point in East Africa. This is likely to be of value also to those working in other fields than plant physiology. For example, the plant pathologist is often concerned with the duration of wet conditions which favour the spread and development of some fungi. Hitherto in East Africa, continuous humidity-recording stations have been lacking and no measurement of the duration of high humidities or even of potential dew during past years has been possible. Now, if there is a temperature-recording station, the mean temperature offers an estimate of the dew point and consideration of the duration of dry bulb temperatures at or below dew point will at least provide a rough estimate of the duration of potentially damp conditions.

50. This work is being continued using monthly means instead of annual means, and an examination of the relationship between dew points and mean monthly minimum temperatures is being undertaken.

SUMMARY OF METEOROLOGICAL OBSERVATIONS AT MUGUGA, 1956

	RAINFALL	AIR TEMPERATURE			AIR HUMIDITY			WIND SPEED	SUNSHINE	OPEN WATER EVAPORATION		
		MONTHLY MEANS OF DAILY VALUES								MONTHLY TOTALS		
	Monthly Totals	Maximum	Minimum	Mean	Dew Point mean of 0830-1600	Saturation Deficit Mean of 0830 and 1600 hrs.	R.H. at 1600 hrs.	Mean Wind Speed at 6 ft. above ground	Mean Daily Sunshine Hours	Sunken Pan Insulated From Soil	Australian Pattern 3 ft. Deep Sunken Tank	Raised Pan with Heavy Grid Cover
	Inches	°F.	°F.	°F.	°F.	mm. of Mercury	%	M.P.H.	Hours	Inches	Inches	Inches
Jan.	4·87	68·0	52·2	60·1	53·6	2·70	66	6·7	6·9	5·04	4·60	5·30
Feb.	1·45	71·5	52·5	62·0	52·1	4·41	50	8·1	9·8	5·94	6·21	7·46
Mar.	3·11	73·1	54·6	63·8	53·4	4·65	51	8·9	8·9	7·50	6·84*	8·13
April	7·97	70·0	54·8	62·4	55·2	3·18	65	7·5	7·5	5·13	5·11	5·51
May	2·92	67·1	52·9	60·0	53·9	2·52	66	5·0	5·4	3·89	3·56	4·11
June	0·12	65·3	49·1	57·2	50·5	2·58	60	4·5	5·4	3·51	3·18	3·88
July	1·22	64·4	44·9	54·7	49·5	2·01	63	3·7	4·5	3·07	2·78	3·38
Aug.	0·72	66·8	47·4	57·1	50·1	2·72	58	4·9	5·9	4·05	3·83	4·45
Sept.	0·97	68·8	48·3	58·5	49·6	3·37	54	5·6	5·5	4·33	2·98	4·55
Oct.	0·66	72·2	51·2	61·7	49·9	4·80	45	7·6	7·9	6·37	6·10	7·10
Nov.	3·61	67·9	52·7	60·4	53·2	3·04	63	9·3	6·4	4·74	4·53	5·55
Dec.	0·44	69·8	52·3	61·1	52·5	3·66	57	9·7	9·5	5·95	6·07	7·26
Annual Totals	28·06	—	—	—	—	—	—	—	—	59·52	55·79	66·68
Annual Means	—	68·7	51·1	59·9	52·0	3·30	58·2	6·8	7·0	—	—	—

*Tank repainted, lost data estimated.

SUMMARY OF METEOROLOGICAL OBSERVATIONS AT MUGUGA, 1957

	RAINFALL	AIR TEMPERATURE			AIR HUMIDITY			WIND SPEED	RADIATION	SUNSHINE	OPEN WATER EVAPORATION		
		MONTHLY MEANS OF DAILY VALUES									MONTHLY TOTALS		
	Monthly Totals	Maximum	Minimum	Mean	Dew Point mean of 0830-1600	Saturation Deficit Mean of 0830 and 1600 hrs.	R.H. at 1600 hrs.	Mean Wind Speed at 6 ft. above ground	Kipp-Moll Solarimeter	Mean Daily Sunshine Hours	Sunken Pan Insulated From Soil	Australian Pattern 3 ft. Deep Sunken Tank	Raised Pan with Heavy Grid Cover
	Inches	°F.	°F.	°F.	°F.	mm. of Mercury	%	M.P.H.	Inches* Water Evaporated	Hours	Inches	Inches	Inches
Jan.	5·11	72·3	51·7	62·1	51·9	4·31	53	7·5	10·76	8·4	6·42	5·04	7·20
Feb.	2·00	70·5	51·8	61·1	52·0	4·15	56	8·3	10·33	9·2	4·48	4·37	4·78
Mar.	0·69	72·8	54·2	63·5	53·9	4·19	54	8·5	10·74	8·4	6·51	6·18	7·38
April	10·28	71·2	55·1	63·3	55·4	3·63	62	7·0	8·81	7·5	5·79	5·17	5·92
May	11·39	67·2	53·6	60·4	56·7	1·72	77	5·1	7·36	5·2	3·65	3·44	3·80
June	5·69	65·7	50·2	58·0	53·9	1·64	72	4·0	8·43	5·6	3·48	3·45	3·45
July	0·77	63·6	48·4	56·0	51·7	1·68	72	4·8	7·53	4·9	3·25	3·03	3·57
Aug.	0·09	64·2	49·2	56·6	50·8	2·21	65	5·8	7·86	4·6	3·59	3·44	3·94
Sept.	1·26	70·2	49·8	60·0	49·8	4·02	48	7·4	11·83	8·5	6·20	5·89	6·61
Oct.	2·33	72·4	52·9	62·6	51·0	4·96	47	8·7	12·08	8·8	7·36	7·00	7·92
Nov.	4·88	68·5	53·6	61·1	54·1	3·04	63	9·5	9·97	7·4	5·41	4·97	6·09
Dec.	3·28	69·5	52·9	61·2	54·9	2·76	65	8·3	9·35	8·6	5·87	5·50	6·38
Annual Totals	47·77	—	—	—	—	—	—	—	115·05	—	62·01	57·48	67·04
Annual Means	—	69·0	52·0	60·5	53·0	3·2	61·2	7·1	—	7·3	—	—	—

*1 inch water evaporated = 1498·6 gm-cals/sq. cm.

SOIL FERTILITY STUDIES

HUMUS DECOMPOSITION AND SOIL NITROGEN

H. F. Birch

51. The problem of humus decomposition has been further studied during the past 18 months and an understanding of the factors involved is now being reached. The pattern of humus decomposition briefly mentioned in the last Report has now been confirmed over a number of seasons. At the start of the rains decomposition is relatively rapid but quickly falls off as wet conditions continue. During the following dry season microbial activity, and therefore decomposition, is practically negligible. At the start of the next rains rapid decomposition again occurs, falling again to a low level as these continue. This pattern of behaviour has been found so far to occur over five successive wet and dry periods. Further, the drier the soil prior to the rains the greater the magnitude of decomposition when these occur.

52. Decomposition of humus should be associated with a proportionate production of nitrate, and these experiments have in fact shown that nitrate production is proportional to the amount of humus decomposed. This has the very important consequence that a large flush of nitrate is produced at the onset of the rains, and this nitrate may be washed out from the soil by subsequent rains unless there are crops growing in the subsoil to take it up. This work therefore explains the experience so commonly found in East Africa of the very great importance of the early planting of annual or short-season crops, for normally it is only these crops that can make the best use of the nitrates produced by the early rains, whilst late-sown crops must make do with the much smaller amounts of nitrates produced by the subsequent slow decomposition of the humus. Intensified soil drying, by maximum exposure to the sun or by the burning of vegetation on the soil surface, will further enhance the amount of nitrate produced when the rains come. This enhanced production can, however, only take place at the expense of the humus reserve in the soil leading to its more rapid depletion with possibly adverse effects on soil structure.

53. This simple pattern of decomposition is of fundamental importance in soil fertility and humus conservation. It demonstrates the important effect of climate on nitrate production and puts the behaviour of the soil, in this respect, on a more predictable basis.

It is also relevant to the interpretation of nitrogen fertilizer trials, the theory underlying certain agricultural practices (e.g. burning and early planting), and the problem of humus build-up and run-down in the soil. In the latter connexion the slow rate of decomposition under prolonged moist conditions is of particular interest.

54. Applications of this pattern of behaviour to soil humus problems can be facilitated, and possibly extended, if the underlying cause is known. It has already been found to depend basically on the fact that more decomposable material of an organic nitrogenous nature can be extracted from a dry soil than a moist one. It was earlier postulated that this organic material was retained within the clay fraction and protected from microbial attack. Drying was assumed to bring a small amount to the surface which, on wetting, became available to the micro-organisms and decomposed. Subsequent experiments showed, however, that this hypothesis was untenable. Decomposition studies with various organic materials in both soil and sand media indicate that the drying effect is simply due to the production of soluble humus. The pattern of decomposition, as affected by different treatments during and after rewetting, conform with the behaviour to be expected following the addition of soluble organic material to the soil. Physical changes in the soil either during drying or on rewetting appear not to be directly responsible for the drying effect. A possible mechanism, now being studied, is that during the last stage of drying, when the relative concentration of monovalent ions in the soil solution is highest, part of the humus is converted to a water-soluble humate. On rewetting, the humate is decomposed and the cations liberated to function again. There is evidence in the literature to support such behaviour and direct proof is now being sought. In any case it is clear that humus decomposition is at least partly governed by a solution process which depends on the drying and wetting cycle and that only a small proportion of the total humus is involved on each occasion. This helps to explain why humus persists in the soil. In this connexion it may be mentioned that after 45 successive oven-dryings and rewettings of a local soil, the organic carbon content has decreased from about 6 to about 4 per cent, but the flush of decomposition on rewetting still occurs though the magnitude is declining steadily as the organic reserve becomes depleted.

55. Most of this work has been done with Muguga soils, but work is in hand on soils in which organic manures, such as

compost and farmyard manure, are known to have a long-lasting effect. The soils being examined come from the experimental farms at Ukiriguru, Tanganyika, and Serere, Uganda. In each area part of the effect of the organic matter is known to be due to the phosphates they contain, but a study of their behaviour in the respirometer should give an indication of how far the manures have effected the nitrate flush produced by the early rains. Soil samples from protected and burnt Miombo areas in Northern Rhodesia have also been studied in the respirometer in connexion with some work being carried out by the Ecologist, E.A.A.F.R.O., who discusses the results in his section of this Report.

THE FERTILIZER REQUIREMENTS OF EAST AFRICAN SOILS

H. F. Birch and M. T. Friend

56. The results of 105 field trials with 18 different crops (mostly carried out by the Kenya Department of Agriculture) have now been studied in relation to the corresponding soil and plant analyses carried out at E.A.A.F.R.O. Plant samples were available from only a few of the experiments. The object of this work was to find out if any relationships could be established between yield and response on the one hand and soil and plant chemical characteristics on the other. Unfortunately little use could be made of the results of the field trials for this purpose. Ideally we required data on the behaviour of a particular crop on a wide range of soils, whereas only one series of trials with maize satisfied this requirement. With the remaining crops, either many of the trials with each crop were carried out on the same soil type, or only two or three trials were carried out with each crop with consequently little spread over different soil types. However some information was obtained which is summarized below:—

(*a*) A marked difference in both control yield and response frequently occurred in different years on the same site. This emphasizes the need for repeated field trials before the potential productivity and responsiveness of a soil can be obtained.

(*b*) The total exchangeable base content of the soil was found to be a good measure of soil productivity with most crops.

(*c*) With maize no significant relationships whatsoever were found between phosphate response and any chemical characteristic of the soil, including the amounts of phosphate extracted by different methods. This is in contrast to findings elsewhere and warrants further study.

(*d*) Residual phosphate responses were found in every experiment in which a phosphate response could have been expected, and were found to occur on quite a variety of soils ranging from pH 5.6 to 6.3.

(*e*) Leaf analyses showed that a given percentage of P in the leaf was often associated with a wide range of yields and responses. Conversely different percentages were sometimes associated with similar yields and responses. Plant size and soil moisture conditions (which will control the soil depth from which the roots derive their phosphate) are complicating factors which make the interpretation of leaf analyses difficult.

57. These fertility studies, in conjunction with the work on humus decomposition and nitrate production, emphasize the need to include the behaviour of the soil (as affected by climate) in soil fertility studies. The amounts of N.P.K., etc., in the surface soil represent only one aspect of soil fertility, indicating the nutrient reserve on which seasonal influences operate. The time of sampling in the field and the subsequent treatment of the samples (whether dried or not before analysis) are factors that should be considered in interpreting soil analytical data.

STUDIES ON SOIL PHOSPHORUS

M. T. Friend

58. The results reported in the previous section that none of the methods of estimating soil phosphorus was of any appreciable value for predicting the response of a crop to phosphate fertilizers added to the soil is sufficiently important for a more detailed study of soil phosphorus to be undertaken. The methods of extracting phosphate from the soil which are being studied include the use of ammonium fluoride, dilute hydrochloric acid, dilute acetic acid containing 8-hydroxyquinoline, and hot sodium hydroxide. This latter has been found to be of value for predicting crop responses for certain Southern Rhodesian sandy soils. For the series of soils so far used the amount of phosphorus extracted by these methods

has not correlated with the actual response of crops to phosphate fertilizers.

59. Some studies have also been undertaken on the residual effects of phosphate fertilizers added to East African soils. It has been claimed in the past that many tropical soils rapidly fix phosphate fertilizers in a form which subsequent crops cannot use, that is the value of phosphate fertilizer on such soils would only be seen for the crop to which it is applied and it would have no residual effect for subsequent crops. On the experimental side none of the few soils for which proper experiments are available have shown any stronger phosphate fixation than is found in normal European soil. But a laboratory estimation of the phosphate-fixing power of a number of soils is being made in the hope that some can be picked out in which phosphate fertilizers might be expected to have a very small residual value. Soils have already been found which can retain much more phosphate than the normal run of soils in temperate regions.

STUDIES OF SULPHUR METABOLISM IN SOILS AND MUDS

P. R. Hesse

60. *The measurement of sulphate in soils and solutions.* Previous studies of the effect of added calcium sulphate on the rate of decomposition of soil organic matter reveals the surprising fact that the more calcium sulphate that was added to a soil the more sulphate was produced by that soil on decomposition. This phenomenon was so surprising that it was re-examined and found to be due to an error in the normal method sulphate determinations. The trouble was traced to the presence of colloidal organic matter in the solution, which need not colour the solution at all, but which interfered with the precipitation of the barium sulphate. A method has been found to overcome this error, and after several other methods had been discarded a simple method was found of co-precipitating the colloidal organic matter with ferric hydroxide and removing it by filtration just before the sulphate is precipitated as barium sulphate. This extra stage so introduced into the procedure takes very little extra time, and not only does it result in the elimination of interfering colloids but it simultaneously removes colour due to any ferric ions present. The details of the experimental procedure have been published.

61. *The mineralization of organic sulphur in soils.* Previous work had shown that the biological oxidation of organic sulphur compounds in Muguga soils was an extremely slow process, less than 5 p.p.m. of SO_4–S being produced after six months' incubation. As a consequence of Birch's findings on the effect of drying and rewetting the soil on the rate of breakdown of organic matter, these earlier results were repeated using Birch's technique. Muguga wattle forest soil after air drying and rewetting gives a small release of soluble sulphate of from 5 to 7 p.p.m. S. Oven drying and rewetting caused the production of over 50 p.p.m. of SO_4–S. A subsidiary trial was made to make certain that none of the sulphate produced was reabsorbed by the clay by extracting the soil with 8-hydroxyquinoline, but this brought out no more sulphate than the water extract, thus proving that no sulphate had been absorbed on the soil particles.

62. *The sulphur status of Lake Victoria mud.* At the request of the East African Fisheries Research Organization further work has been carried out on these problems.

63. The background of this work was given in last year's Report. The Lake waters are very low in sulphur yet the muds at the bottom of the Lake are high. There is, however, very little sulphide present in the muds although there appears to be a considerable amount of sulphates. It has been found that much of this sulphate is held on diatomaceous silica present in the mud, and investigations have now shown that this sorption occurs through the medium of calcium ions and not of iron aluminium ions as was expected.

64. Another important factor which needs explanation is why the organic sulphur in the Lake mud decomposes with so much difficulty. This question has not yet been answered, but it has been shown it is not due to any antibiotics or other inhibitors of microbiological activity in the fresh mud. Part of the reason appears to be that the organic matter there has already suffered considerable decomposition and the material that accumulates is inherently resistant to decomposition. The fresh mud has been found to contain 16 per cent of lignin on a dry weight basis, which corresponds to the value for cattle faeces. On drying and rewetting this mud decomposition proceeds in the same way as Birch has found for soils, namely a flush of decomposition takes place for a short time, during which a considerable amount of carbon, nitrogen and sulphur are mineralized, but the rate drops rapidly,

unlike soils, and further repeated redrying and rewettings give flushes of decomposition of rapidly decreasing magnitude which only cause the oxidation of a small proportion of the organic matter present in the mud.

65. *Nitrification in a rewetted air-dried soil.* A local forest soil which had been air-dried for several weeks was rewetted to optimum moisture content and equal aliquots incubated in Birch's respirometer. Samples were removed daily and analysed for nitrates and ammonia and the oxygen uptake and carbon dioxide evolution were determined. The results showed that when the flush of carbon dioxide evolution was over, and the soil has reached its equilibrium status of low decomposition, the production of nitrates had also ceased, and in fact the production of nitrates followed the evolution of carbon dioxide as one would expect. During the first 15 days of incubation the nitrate content of the soil increased by 100 p.p.m. N, and no more was produced during the next 50 days. This 100 p.p.m. of nitrate nitrogen liberated during the 15 days flush of decomposition is equivalent to 200 lb. of nitrogen in the top 6 inches of the soil per acre, which corresponds to nearly $\frac{1}{2}$ ton of sulphate of ammonia.

66. *Advisory work.* During the past 18 months, Dr. Birch attended the meetings of a Kenya Committee enquiring into the the reasons for the decline in the quality of the flour made from some local wheats.

ANALYTICAL SERVICES: CHEMICAL

M. T. Friend

67. This section is mainly concerned with the analysis of soils and plants submitted by various research officers and departments. The following soil analyses have been carried out during the period under review.

Soil Survey Section. A total of 333 soils from Kenya and Tanganyika were analysed for pH, carbon, nitrogen, coarse and fine sand, silt, clay and organic matter.

Physics Division. Six soils from a proposed irrigation site in Tanganyika were tested for pH, and the electrical conductivities measured on the saturation extract from these soils.

Ecological Section. Eight soils from burnt and unburnt grazing land were analysed for pH, carbon, nitrogen, clay, silt and sand and phosphorus.

Horticultural Section. Five soils were analysed for pH, carbon, nitrogen and phosphorus.

Muguga Field Experiments. 24 soils from lucerne and nitrogen conservation trials were analysed for pH, carbon, nitrogen, sand, silt and clay and for three forms of phosphorus.

Pyrethrum Station, Kenya. Two soils were analysed for pH, carbon, nitrogen, sand, silt and clay and for three forms of phosphorus.

Forest Department, Kenya. Six soils were analysed for pH, carbon, nitrogen and phosphorus.

Perkerra Irrigation Scheme, Lake Baringo. One soil was analysed for pH, carbon, nitrogen, sand, silt and clay and phosphorus.

E.A. Implement and Tractor Testing Unit. 30 soils were analysed for clay and sand in conjunction with uniformity tests, and two soils from Serere, Uganda, for pH, carbon, nitrogen, sand, silt and clay.

68. *Water analyses.* During November and December, 1956, an ecological survey of the Serengeti National Park, Tanganyika, was carried out by Professor W. H. Pearsall for the Fauna Preservation Society. 17 water samples collected by Professor Pearsall from various waterholes and streams in the Serengeti Park were sent to E.A.A.F.R.O. for analysis. The pH and electrical conductivities were measured and the carbonate, chloride and fluoride contents determined. These results have been included in Professor Pearsall's report for the Fauna Preservation Society, London.

69. *Soil carbon determination.* The carbon-nitrogen ratios of some deep subsoils in East Africa have been found to be as low as 3 or 4 when the carbon was determined by the Walkley-Black method and the nitrogen by the Kjeldahl. Since it is extremely unlikely that there are any organic compounds in the soil with as low a carbon-nitrogen ratio as this, the suitability of the Walkley-Black method for determining the organic carbon in subsoils was examined. In normal surface soils the Walkley-Black method estimates about 70 per cent of the soil carbon, and this factor of 70 per cent recovery was assumed to apply to the deep subsoil as well. The organic carbon in a number of these subsoils was, in consequence, determined by the Tinsley method where 97–99 per cent recovery of organic carbon is claimed. It was found that for soils containing over 1.3 per cent carbon the Walkley-Black method gives 60–70 per cent of the carbon given by Tinsley as expected, but for subsoils containing less than about 0.1 per cent carbon it only gave 15–35 per cent of the Tinsley figure. The carbon-nitrogen ratios, therefore, of these deep subsoils, using the Tinsley instead of the Walkley-Black carbon become reasonable.

ANALYTICAL SERVICES: SPECTROCHEMICAL

G. T. Chamberlain

70. The Division has continued the analysis of soils and plants for bases and trace elements in connexion with nutritional problems and survey work.

71. A total of 472 soils, 109 plants and 20 other samples have been analysed for bases by the Lundegard flame method and 208 plants and 139 different soils for extractable trace elements. Experimental work on the extraction of trace elements from soils has mean several extractions for some soils, and overall the equivalent of a further 105 soils has been analysed.

72. Owing to the very considerable demands for analysis made on the Division it has not been possible to carry out all the development work that was desired. The flame photometer for potassium determination is in course of construction and good progress has been made in modifying the trace element methods so that a greater throughput of samples will become possible. The latter developments are due to the purchase of the "Respektra" calculating board which coupled with modifications in technique can considerably reduce the work involved in evaluating microphotometric data.

73. *Bases in Soils, Plants, etc.* The majority of the soils analysed were for the E.A.A.F.R.O. Soil Survey Division (150) and from fertilizer experiments for the Department of Agriculture, Kenya (111). In addition 68 soils were analysed for the Ecologist (E.A.A.F.R.O.) including soils from a Northern Rhodesia grass-burning investigation. For the Physics Division (E.A.A.F.R.O.) exchangeable and water-soluble bases were determined in soils from potentially irrigable areas. The remaining samples were routine determination of bases on samples received for the trace element investigations which are described below.

74. The plant samples analysed for bases were mainly from trace element investigations. Exceptions were 31 samples of coffee leaf and crop analysed for the Coffee Research Station, Ruiru, Kenya in connexion with their research, jointly with the Department of Agriculture, Uganda, into magnesium deficiency in coffee. The data from these samples are being included in their joint report.

75. Calcium in 16 natural waters from the Serengeti Plains, Tanganyika, was determined for Professor W. H. Pearsall on behalf of the Fauna Preservation Society, London. Calcium in two fertilizer samples was determined for the Horticulturist, E.A.A.F.R.O.

76. *Trace Elements in Soils and Plants.* Considerable progress has been made in the improvement of our knowledge of the trace element status of East African soils and plants.

77. It was stated in the previous Annual Report that analyses of soils from good and bad pastures in the Nakuru (Kenya) area revealed little difference between them. Further work has shown that soils from satisfactory pastures contain more than 0.07 p.p.m. cobalt and 4.8 p.p.m. copper, whilst soils from unsatisfactory pastures contain less than 0.04 p.p.m. cobalt and 2.0 p.p.m. in copper. These contents of cobalt and copper fall within the range for marginal and deficient pastures in the United Kingdom and elsewhere. Analyses of other soils and pastures from the Rift Valley between Nakuru and Kedong have revealed an overall low level of soil cobalt, generally around 0.05 p.p.m., thus it appears that the whole of this area is at the best marginal. It is believed that these are the first analytical data to confirm the well-known inadequacy of the cobalt and copper status of the pastures for cattle in this area.

78. *Milk Taint.*—Samples from Elementeita and Naivasha analysed at the request of the Department of Veterinary Services, Kenya, provided some of the information referred to above but their prime purpose was to see if any trace element might be concerned in causing "milk taint". The significant change in the pastures from non-taint to taint areas which was observed was in the case of molybdenum, this increasing from 5 to 14 p.p.m. It is too early to state whether this is in any way related to the taint and further samples of pasture and milk are to be analysed.

79. These high molybdenum values for otherwise normal pasture led to the desirability of finding a suitable reagent for the extraction of soil molybdenum as the usual 0.5 N acetic acid employed hitherto is unsuitable for this purpose. Solutions of 0.1 N sodium hydroxide, N ammonium acetate and 0.5 N acetic acid plus 1 per cent 8-hydroxyquinoline were used experimentally.

The first was discarded because of the large amounts of iron and aluminium which it extracted. Attempts to remove the iron

by mercury cathode electrolysis were of no avail due to the fact that molybdenum was removed simultaneously. Another possible method might be electrolysis at a controlled potential, but the apparatus for this was not available. Both the two other reagents tried were found to be satisfactory at low molybdenum contents but the ammonium acetate was more suitable at higher contents and was therefore adopted.

80. For the Naivasha soils the ammonium acetate extracted up to 1.0 p.p.m. of molybdenum from the soils of the pastures giving "milk taint" but only about 0.1 p.p.m. from the "non-taint" pastures, thus confirming the increases in the pasture grasses. The highest molybdenum contents were obtained in areas of old lake bed as revealed by the high potassium and sodium contents, and the subsoils contained even greater amounts of molybdenum (2.4 p.p.m.). It is hoped to determine if this accumulation of molybdenum is a general feature of these lake areas during the course of future work.

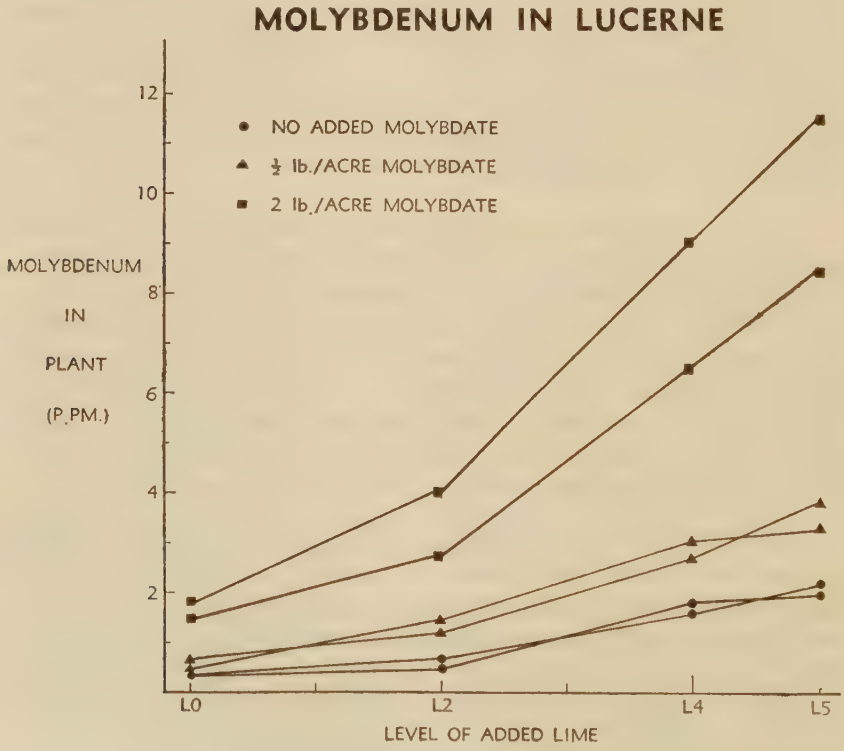

Figure 1

81. *Miscellaneous Analyses.* For the Coffee Research Station, Ruiru, Kenya, 32 samples of coffee leaf have been analysed. 22 of these samples were from an experiment to determine the effect of the addition of trace element fertilizers to coffee soils but as yet no reflection of the treatments has been observed in the leaf analyses. Four samples were of chlorotic and normal leaf but no significant differences were obtained, and the remaining six were from trees showing zinc deficiency. Four of these samples had zinc contents inversely related to the severity of the symptoms observed in the field. Further analyses are to be carried out.

82. Other branches of the Kenya Department of Agriculture have requested analyses on a variety of plant materials, e.g. seradella, lucerne, wheat, passion fruit and pyrethrum. For seradella and lucerne responses were obtained from molybdenum fertilizers in the Molo area and in the latter crop a combined lime-molybdenum experiment yielded very interesting results. One-half pound per acre of molybdate gave a response over control but two pounds gave no response. Plant analyses revealed a systematic increase in molybdenum content (*a*) with lime alone, (*b*) molybdenum alone, and (*c*) lime and molybdenum together. The results are shown in Figure 1 opposite and it is interesting to note that potentially toxic quantities of molybdenum are present in the lucerne derived from the highest treatments of lime with molybdenum.

83. In the case of wheat, the samples were from a liming experiment at Kaptagat and again showed an increase in the uptake of molybdenum at the higher levels of liming. The pyrethrum samples were young and old growth from plots treated with gypsum and basic slag. No differences in composition were observed which could be attributable to the treatments. The passion fruit samples were from the Sotik area and were suffering from a disease known as "woodiness" and also much reduced yields have been obtained in recent years. Although the principal cause of this disease is known to be a virus, a check on the mineral composition of the plants was wanted, to check any possible abnormality. Preliminary analyses have not shown any.

84. At the request of the Kawanda Research Station, Uganda, boron determinations have been carried out in eucalyptus trees and also from the tea plant grown in pot culture. For the former there was one instance in which the boron deficient leaf was much lower than control but a second pair of samples did not show this.

For the tea samples, three deficient samples showed markedly less boron than their respective controls.

85. From the Tanganyika Agricultural Corporation, Nachingwea, soil and plant samples were received representing healthy and unhealthy sorghum from a region of very acid soil. It was found that the unhealthy areas coincided with extreme acid soil conditions and low saturation of the base exchange capacity (less than 15 per cent saturated), while the healthy areas were more saturated (more than 30 per cent). Also there was a relationship between the degree of base saturation of the soil and the molybdenum content of the leaf samples. Further investigations are being carried out jointly by the Tanganyika Agricultural Corporation, the Kawanda Research Station, Uganda, and this laboratory to determine the precise cause of the lack of growth of the sorghum. Possibilities are that the effect is (*a*) due solely to the acidity, (*b*) manganese toxicity due to the acidity, or (*c*) molybdenum deficiency induced by the acidity.

86. Samples have been received from the Department of Agriculture, Tanganyika, for examination in connexion with serious chlorosis of wheat and barley occurring in the Mt. Kilimanjaro area and also in connexion with a phenomenon in beans known as "oily pod". In the case of both wheat and barley the chlorotic samples showed slightly lower contents of copper and manganese and higher of molybdenum, vanadium, cobalt and titanium than the controls. Further analyses are to be carried out.

87. Concurrently with the above investigations and supplementing their soil analyses, samples of soil collected by the Soil Survey Division have been analysed for trace elements to cover representative soils of East Africa. In all some 244 extractions of 139 soils have been carried out and much important information has been obtained. Of particular interest has been the varying behaviour of the different trace elements towards the extractants. With cobalt and nickel considerably less was extracted by ammonium acetate and acetic acid plus 8-hydroxyquinoline than by acetic acid. For molybdenum it has been shown above that the reverse was the case but figures for vanadium indicated that the behaviour of this element in the chemistry of the soil was unexpectedly different from molybdenum. Whereas the ammonium acetate extracted more molybdenum than the acid-quinoline reagent, the latter extracted 20–30 times the vanadium than the former when vanadium was present in any quantity (i.e. 1 p.p.m. or more).

Further study of these extraction effects including other extracting agents is to be carried out, and in particular it is desired to relate the amount extracted from the soil to that taken up by plants.

88. Other analyses which have been made during the period have been further grass and legume samples grown in Muguga, and a few crop samples from occasional farms where abnormalities have been reported. 12 samples of leaf and needles from trees grown in the Muguga Arboretum have been analysed as a preliminary to the study of forestry problems and here again marked differences were observed in the uptake of trace elements by different tree species.

89. The experiments with lupin referred to in the previous Annual Report are proceeding: the molybdenum exhaustion trial has completed four crops, the fifth having just started (November, 1957); the green manuring experiment is now growing the indicator crop and the species-composition trial has been sampled and is awaiting analysis.

90. For the Forest Department, Kenya, 26 samples of the periphery and centre of pine poles were analysed to obtain the degree of penetration of a preservative. It was shown that in some instances complete penetration was not effected.

91. *Advisory Work and Visits.* It has not been possible to carry out many visits during the period due to the pressure of analysis but visits were made to the Sisal Research Station, Mlingano, Tanganyika, in January and in June. The Spectrochemical laboratory at the Research Station is now analysing soils and plants for trace elements but an exchange of data is continuing. A brief visit was also made to Kawanda Research Station, Uganda.

SOIL MICROBIOLOGY

J. W. Millbank

92. Work in the Microbiology Section has continued on the nitrogen status of Kikuyu red loam soils with particular emphasis on nitrification and the Legume-Rhizobium symbiosis. Towards the latter part of the year Mrs. M. A. Ledger joined the Section as Scientific Assistant, and has been occupied with assay work and supervision of the greenhouse experiments.

93. *Nitrification.* The process is being studied with a Lees-Quastel perfusion apparatus, and up to the present Kikuyu red loam from the Muguga estate is the only soil type that is being used. Most of the work has been done with a surface soil under a Kikuyu grass sward, but some observations have also been made with topsoil from arable land and from a wattle plantation.

94. The shape of the curve relating the amount of nitrate produced with the time was sigmoid, which is almost conclusive evidence that the process is brought about by proliferating cells. A noticeable feature of the curve was a particularly long lag phase which was only slightly shorter when so-called "good" local soils were used. This lag phase could be as long as eight to ten days. In the initial experiments only 35 to 40 per cent of the available ammonia was nitrified due to the pH of the soil in the perfusing liquid falling to below 5, consequent upon the low base reserves in the soil.

95. The effect of adding calcium carbonate to the soil on its rate of nitrification was found to be a decrease in the lag phase, an increase in the rate of oxidation of ammonia, and quantitative conversion of the ammonia to nitrate. If fairly large amounts of calcium carbonate were added to the soil, such as 1 g. to 40 g. of soil, nitrite was found to accumulate after a few days, though very large accumulations of nitrite were found in the perfusing liquid, and as much as 200 μ g NO_2 –N/ml. in the perfusate out of a possible 280. The nitrite concentration then diminished rapidly, and the nitrate built up to its expected level, the nitrite phase extending over about eight days. The addition of smaller quantities of calcium carbonate to the soil gave rise to smaller nitrite accumulations, but even when the minimum calculated amount was added (0.2 g.), which was quite effective in promoting rapid nitrification although the pH was in the range of 5.9 and 6.1 there was still a transient accumulation of nitrite up to about 100 μ g N/ml.

96. The cause of this nitrite accumulation is presumably because in this soil *Nitrosomonas* develop faster than *Nitrobacter*. This is in accord with the observation that if, after the soil has been perfused with ammonium sulphate, it is washed to remove the nitrate formed and then re-perfused with fresh ammonium sulphate, the conversion to nitrate is immediate and rapid: it proceeds at a constant rate, and no nitrite is found to accumulate even though calcium carbonate had been added to the soil. Magnesium carbonate added to the soil gave the same results as

calcium carbonate, but if the soil was buffered with dicalcium phosphate, or with a phosphate buffer, at pH 7, no nitrite accumulated, although the nitrification rate was appreciably slower than when the carbonates were used.

97. *Effect of Inhibitors.* (*a*) *Chlorate.* The effects of ion on nitrification are in many respects similar to those observed by Quastel and Lees in Europe. If the Muguga soil to which some calcium carbonate has been added is pre-enriched with *Nitrosomonas* and *Nitrobacter* by a perfusion of ammonium sulphate, and then is subsequently perfused with ammonium sulphate containing potassium chlorate (5×10^{-4}M), the chlorate inhibits oxidation by *Nitrobacter* and the ammonium is oxidized quantitatively to nitrite, which is only slowly converted to nitrate as the effect of the chlorate on the *Nitrobacter* wears off. This behaviour is typical of the soils examined by Lees. But if the chlorate is added to the ammonium sulphate solution which is perfused through unenriched Muguga soil, the chlorate does not entirely inhibit nitrate formation. Nitrite begins to accumulate, but when about 20 per cent of the ammonium is in this form, nitrates start to appear, and the nitrite concentration begins to decrease. The explanation is probably that the population of *Nitrosomonas* builds up so slowly in the Muguga soil (although it builds up much quicker than *Nitrobacter*) that by the time it has become active the effects of the chlorate on the *Nitrobacter* are wearing off.

(*b*) *Kikuyu Grass Extract.* An aqueous extract of Kikuyu grass was prepared by macerating leaves with water in a homogeniser. The "brei" was strained through muslin to remove large particles and stored in the refrigerator. It was used diluted to one-half. No noticeable inhibitory effect was observed when it was perfused either through soil taken from under a Kikuyu grass pasture or from under a wattle plantation.

(*c*) *Methionine and Histidine.* These amino acids have the same marked inhibitory effect on nitrification in Muguga soil as in European soils. It seems, therefore, that the *Nitrosomonas* and *Nitrobacter* strains present in Muguga soil are physiologically very similar to those present in European soils, and they may be identical.

98. *Legumes and Soil Improvement.* The work in this field is developing along two principal lines: firstly to compare the

efficiency of different crop and pasture legumes on the nitrogen status of tropical soils, and secondly to determine if any special problems arise in inoculating legumes with strains of *Rhizobia* which do not occur naturally. This work is only just commencing, but already it is clear that some of the *Rhizobia* naturally present in the Muguga soil have a different range of host legumes than in temperate regions. Again, preliminary work confirms that the standard technique for inoculating legumes with *Rhizobia* which do not occur naturally in the Muguga soil is quite satisfactory. The present stage of this work is testing if the soil has any specific effect on the efficiency of an introduced strain. This is being done by growing lucerne inoculated with a variety of strains in sand-vermiculite mixtures and in the Muguga soil, for this does not naturally contain any efficient lucerne strain. At the present time the lucerne strains being used in East Africa have been selected on the basis of their behaviour with lucerne in laboratory media.

SOIL SURVEY

G. H. Gethin Jones and R. M. Scott

99. The principal work of this Division for the period under review has been completing the compilation of the Kenya and Tanganyika data for the new edition of a Soil Map of East Africa on the scale of 1 : 2 million, the production of the master copy of this map for these two Territories, and the drafting of a suitable memoir to accompany the map. It had been planned to have the map ready for publication early in 1958, but it has been decided to withhold publication until the soil survey of Uganda, which is being carried out on a scale of 1 : $\frac{1}{4}$-million under Dr. E. M. Chenery is complete. This will involve a delay of about two years, but will result in a far more accurate map for Uganda than is possible at the present time, and it will also allow for more work to be done in a few areas of Kenya and Tanganyika which have not been adequately examined.

100. The soil map for Kenya and Tanganyika cannot be based on a complete soil survey of the whole region. It has been therefore necessary to extract the relevant information on their soils from all available sources, and to assess its reliability, and reclassify the soils on our new system. The principal source for Tanganyika has been the work done by Milne, which was summarized in his Provisional Soil Map of East Africa and published

in 1936. In addition, the following sources have been used; for the Southern Province of Tanganyika, information on soils and their boundaries, which was prepared for the Report of the Central Africa Rail-Link Development Survey; for Kenya, certain areas where E.A.A.F.R.O. staff have prepared detailed large-scale soil maps; for part of South-West Kenya, a general soils map prepared by E. Bellis, the Chemist in the Department of Agriculture, Kenya. In addition, a mass of field notes on Kenya soils, collected by Gethin Jones and Beckley over the past 25 years, has been drawn upon. But all these sources left large areas of Kenya and Tanganyika undescribed, and in consequence a number of reconnaissance surveys have been made along roads and tracks to collect data on the distribution of the soils in these areas, using the method described in last year's Report.

101. The basis of the classification of the soils into classes has been on soil-site, soil-profile and selected physical and chemical characteristics. It has not been possible to use the proportion of the various clay minerals present in the soils, as there are no adequate facilities at Muguga for doing this. No sub-divisions have normally been made for soils derived from different parent geological strata, unless the effect of the parent material was sufficiently reflected in the profile. This generally only happens where the parent material contains large amounts of grit or coarse sand, such as soils derived from coarse-grained siliceous granite or where it is a pale pink highly kaolinitic material giving rise to a characteristic pinkish-red leached soil.

102. The classification used is a modification of that given in the two previous Annual Reports of this Organization. The soil types which have been recognized have not been made to fit into the present-day conventional soil groups for tropical and sub-tropical soils, partly because many of such divisions are not adequately defined by specific pedological data, and partly because the present conventional groups are still inadequate for many East African soils.

103. One of the problems which has always faced every compiler of a soil map, particularly in tropical regions, is the problem of delineating those areas where the soils are so inter-mixed that the boundaries of each soil type cannot be shown separately on the map. A satisfactory solution of this problem has been found when the cause of the variation lies primarily in the topography, for the sequence of soils found from the hilltops to

the valley bottoms are grouped into a catenary sequence, as described in last year's Report. But in other cases the range of the soils included in a given soil type has had to be widened. This can be illustrated by the definition of the so-called black cotton soils used in the map. During the early period of the survey, attempts were made to break these down into four groups, based on whether they were calcareous or non-calcareous soils, and whether they had been formed from hard crystalline rocks or were the altered products of previously weathered transported old lake bed material. Although areas have been found where one or more of these four groups occur over sufficiently wide areas so each can be mapped, yet in general it has been found that these low-lying black cotton soils comprise such a mixture of non-calcareous and calcareous facies that it is not practicable to subdivide them on the map, and there is frequently evidence in the soils derived from hard crystalline rocks that they contain some transported material.

104. The following four examples illustrate the way different pedological or chemical criteria have been used to subdivide major classes of soils into units which can be shown on the map.

(*a*) Highly coloured soils which have been subjected to varying amounts of leaching. These have been divided into six sub-classes on the basis of such properties as their organic matter content, colour, structure, porosity, consistency, the presence of different kinds of ferruginous concretions, and certain chemical properties such as their cation exchange capacity and percentage base saturation. These six soil classes are usually, but not always, associated with the present climate and vegetation, and the misfits are probably relic soils formed under an earlier more humid climate. As a ready method of recognition the soil class is usually defined by a range of soil colours, often with the subsoil colour taken into consideration as well.

(*b*) Light-coloured sandy soils occurring on gentle slopes in peneplain country. The upper members of this group are well drained and orange in colour, and as one goes down the slope there is an increasing amount of water-logging during the wet season and the colour goes from orange through yellow and yellow-grey to grey. This has been divided into sub-classes on the basis of the degree of water-logging, and the depth and quantity of iron concretions in the soil, which becomes shallower and more abundant the more severe the water-logging. The depth of the grey horizon also increases with increasing extent of water-logging.

(*c*) Youthful soils derived from volcanic ash, which do not show a developed morphology, have been divided into those soils in which soil-forming processes have clearly been at work giving a slightly acid dark surface soil over a yellow-brown to orange-brown ashy subsoil, and those where they have not and the soil is dark throughout the profile with a slight deposition of soluble salts and calcium carbonate in the subsoil. The former soil class, which shows a pedalfer development, includes some of the most fertile soils in the Kenya Highlands. There is also a group of black dusty very high humic ash-derived soils with about 10 per cent of organic carbon in the surface soil, which are considered to be sufficiently different to be put into a third class.

(*d*) Soils in which soil-forming processes have hardly yet affected the profile. A number of separate classes have had to be allowed for these, such as those for little altered volcanic ash, recent alluvium, loose sand, lava plains and shallow stony soils from which much of the finer material has been blown out.

105. Work on the classification of East African soils is becoming increasingly easier to undertake as our collection of soil monoliths, that is soil samples taken from the various horizons in a profile, is increasing. At the present time there are over 400 representative monoliths in the collection, and it is far the most complete collection in East Africa.

106. *Applied Pedology.* In the Soil Map, the soils have been described, classified and mapped on the basis of their own inherent properties without direct reference to their value for agriculture. Many of the individual soils shown on the map will have much the same properties, and therefore much the same agricultural potential, but also suffer from much the same limitations and offer much the same difficulties for good farming, wherever they are found. This does not always apply, both because the conditions under which some of the soils have been formed reflects the past rather than the present-day climate, and also because sometimes the variations which much be accepted in the properties of soils which are grouped together in one class, which is necessary for a given class to have a wide enough distribution geographically to be shown on a 1 : 2 million map, is so wide that it embraces soils which offer distinctly different agricultural problems if they are to be farmed efficiently. Naturally these considerations are borne in mind when one is setting up the criteria to be adopted for putting slightly differing soils into the same or into different classes.

A soil map is therefore of considerable value in showing the distribution of soils which require similar agricultural practices or respond similarly to improved practices, and it should be of considerable help in ensuring a suitable distribution of field experiments over any given area.

107. But there is also the need to translate the soil map of East Africa into a map and inventory of land resources, and this may involve the splitting up or the grouping together of particular soil units according to common factors relating mainly to the agricultural properties of the soil or to the site, and to the present rainfall. Changes in soil type are in general of more importance in effecting land value or land use in areas of adequate rainfall, because in these regions there is a wider choice of crops and methods of husbandry. As the rainfall decreases or becomes less reliable, water increasingly becomes a dominant factor affecting agriculture, the soil becomes of decreasing importance, and increasing reliance must be placed on stock husbandry. One great value of a soil map under these drier conditions is that it should show the areas where any particular trace element deficiency, such as cobalt and copper, is most likely to occur. As pointed out in the last Annual Report a true land resources map must also take account of such factors as the availability of domestic water supplies throughout the year, the incidence of endemic diseases both of man and stock, and of other economic and social considerations, but none of this is part of a soils map, and so cannot be taken directly from it.

PLANT IMPROVEMENT AND PROTECTION

CASSAVA

L. R. Doughty, D. W. Gourlay and D. L. Jennings

108. *Breeding.* No more breeding has been done since that reported in the previous Annual Report. This last phase was concerned mainly with an attempt to produce virus-resistant, bitter types of cassava that would prove resistant to pig damage.

109. During the period under review we have therefore been concerned with field trials and selection of material showing enhanced resistance to disease combined with high yield of a palatable root.

110. While no clone has yet been found which is immune to mosaic, and those which combine the highest level of resistance with high yield are still few and far between, clones equal to the best produced in the early days of cassava breeding are now relatively common. The levels of resistance and yield required for a claim for retention as a potential parent at the present day are therefore considerably higher than in the earlier years, and many of the clones that were being retained for breeding have recently been discarded.

111. *Field Trials.* Resistance trials of the remainder of the extensive 1954 series of crosses and of the 1955 series occupied to capacity our trial plot at the Sisal Research Station, Mlingano, Tanga. Establishment in these trials was well below average, due to the virtual failure of the short rains in 1956, but this was not altogether a disadvantage, as it assisted in the elimination of the less hardy clones. Rainfall in 1957 was satisfactory, and after a poor start plants which did establish made a good recovery.

112. The harvest of these trials has not been completed but indications are that the ceara × cassava back crosses and their intercrosses provide the most hopeful sources of varieties which combine high yield with resistance to both mosaic and brown streak. Crosses between derivatives from the 4032 line, a first back cross of ceara × cassava to cassava, which has produced the most successful clones to date, and derivatives of other B1 ceara

hybrid lines have produced a high proportion of mosaic-resistant clones but the indications are that they are inferior in yield to crosses within the 4032 line.

113. Crosses between ceara × cassava hybrids and Melanobasis × cassava hybrids have so far produced the biggest proportion of high-yielding clones, but unfortunately their resistance to viruses, particularly brown streak, is proving unsatisfactory. Establishment in these intercrosses also tends to be poor. It is possible that further crossing to increase the thickness of the stem and the size of the leaf would have beneficial results.

114. Crosses between ceara × cassava derivatives and those from Dichotoma × cassava have produced a fair proportion of mosaic-resistant clones, but, with few exceptions these tend to be poor yielders or susceptible to brown streak. Fertility in these crosses is generally low.

115. *Distribution.* Cuttings from five clones, selected from the 1953 series of crosses, were distributed in 1956 to the Departments of Agriculture in Kenya, Tanganyika and Zanzibar for further trial in the coastal region. A selection of seeds from Amani hybrids was also sent to Northern Rhodesia.

116. Extensive collections of material still under trial were also established at Ukiriguru, Mwanza, and Kakamega where they could be kept under close observation for brown streak, which does not, so far as is known, occur naturally in these regions, and which might possibly be disseminated in cuttings from Amani unless distribution is closely supervised.

117. Reports from Matuga (Kenya), Tanga (Tanganyika) and Zanzibar indicate that the five 53-series clones are very promising in respect of disease resistance.

STUDIES ON THE MOSAIC VIRUS OF CASSAVA

D. L. Jennings

118. At the present time the only available means for recognizing the presence of the mosaic virus is the appearance of symptoms in the young leaves of a cassava plant.

119. The method of transmission of the virus has been reported by Storey and Nichols[1]; and more recent observations

in the field indicate that environment influences the production of symptoms in the more highly resistant types that have been produced by breeding.

120. These highly resistant clones usually have only a small proportion of plants producing symptoms, and the symptoms usually appear later in the season than in more susceptible ones. Symptoms are usually mild and may be transient, but observation and experiment have shown that symptomless plants can be carriers of the virus. Symptoms of mosiac have developed on young shoots of cuttings taken from plants that have gone through a resistance trial without producing symptoms. These diseased shoots are usually produced on cuttings taken from the basal portions of stems of the apparently clean plants.

121. It has also been observed that treatments causing a diversion of growth activity, such as plucking the tips from growing branches or pruning such branches, may result in the appearance of symptoms in the young leaves of plants that were previously symptom-free. This type of treatment has been utilized as a means of discriminating between clones with a very high level of apparent resistance to mosaic.

122. The work of Storey and Nichols on Mbarika, a cassava clone then regarded as moderately resistant, showed that the mosaic virus was not fully systemic in the host. It is not known whether the same holds good for the most susceptible clones. In the more recently produced hybrids the mosaic virus is definitely not fully systemic.

123. Storey and Nichols also showed that in Mbarika the mosaic virus moved rapidly downward in an inoculated plant and only slowly laterally or upwards. It seems that in resistant clones the host-virus interaction is such that the virus most frequently passes downwards without causing symptoms to appear or after causing only a transient appearance of mild symptoms. As it is possible to get diseased shoots arising from cuttings from symptom-free plants, it also seems that the mosaic virus is not, or at least not completely, inactivated in a resistant host plant. Resistance therefore appears to be, at least in part, an ability to move the virus rapidly to parts of the plant where it can do no harm to the host.

124. Amongst the latest hybrids raised there are a few clones that have remained, to date, free from symptoms under the most

severe conditions, but it is not known if this field immunity will be maintained through the period of multiplication in a region where the disease is severe.

[1] Storey, H. H., and Nichols, R. F. W. (1938). Studies of the Mosaic Diseases of Cassava. *Ann. appl. Biol.*, 25, 790; and Storey, H. H., and Nichols, R. F. W. (1938). A Field Experiment in the Transmission of Cassava Mosaic. *E. Afr. agric. J.*, 3, 446.

APPLICATION OF THE BRIEGER METHOD TO MAIZE BREEDING

L. R. Doughty and T. Graham

125. The work under this heading is a continuation of the study of the application of Brieger's methods for the study of the production of self-maintaining lines of synthetic maize. As recorded in the last Annual Report top cross seed of the first series of selected lines of inbred material was planted in a series of experiments in March, 1956.

126. Three types of maize are being used in these experiments, viz. (1) Nyanza maize, a collection of material from the Northern, Central and Southern divisions of the Nyanza Province of Kenya; (2) Katumbili maize, from the Lake Province of Tanganyika; and (3) a yellow type from the coast of Tanganyika. All three are being treated in a similar manner with most emphasis on the Nyanza type.

127. The maize was subjected to varying intensities of inbreeding and thereafter top crossed and tested in variety trials for selection of the highest yielders before attempting to synthesise the end product of the experiments. Lines that have been inbred by selfing are designated S1, S2, and S3, depending on the number of times the particular line has been inbred and similarly sibs are indicated by Si1, Si2, and Si3. Intrafamily crosses in S2 are indicated by S2x.

128. The 1956 programme included two yield trials of top cross seed of S3's and S2x's derived from Nyanza-type maize, a trial of similar material derived from Katumbili maize and two trials with top cross seed of S1 and S2 Nyanza material. In addition S3 and Si3 Nyanza material and yellow maize was top crossed for trials in 1957 and more Katumbili material carried to the Si3 generation. The experiments with the earlier maturing Katumbili

type of maize suffered severely from the depredations of porcupines and man. Those planted with later maturing maize were concluded satisfactorily.

129. The mean yields for the S3 top cross variety trials with Nyanza maize were about 17 bags (200 lb.) of grain per acre. Only five out of the 192 varieties in the trials exceeded the mean yield by a significant margin; their yields ranged between 24.4 and 26.4 bags per acre. The S2 top cross trial gave a mean yield of 13 bags of grain per acre and 12 out of the 81 varieties exceeded this figure by a significant amount, all falling within a yield range of 16.8–24.7 bags per acre grain. Only two out of these 12 top crosses exceeded the yield of the better of the two parental types included in the trial by a significant margin. The trial of S1 top crosses gave a mean yield of 9½ bags per acre being on the block with the poorest soil. Five varieties giving yields within the range 13.2–14.6 bags per acre were selected from the 49 in this trial. Of the 13 varieties of S1 top cross yellow maize only two varieties gave yields significantly better than the mean yield 19.3 bags. One gave 25.9 bags and the other 23.2 bags.

130. The 1957 programme includes three trials of Si3 top crosses of Nyanza origin, one of yellow maize of like breeding, some 500 lines of Nyanza maize, and 55 Katumbili lines for top crossing, and the leaders of the 1956 top cross trials for intercrossing for the production of the first synthetic generation. As we have inadequate facilities for growing these last mentioned in groups, in isolation, the synthetic seed has been produced by hand pollination. A top cross trial with Katumbili maize had to be abandoned because of porcupine damage. The breeding plots of this variety were saved from a similar fate as they were planted adjacent to the labour lines.

131. Two confirmatory trials, to retest the findings at Eldoret in 1956, were planted at Kakamega and, on the incomplete results available, show only minor discrepancies in our placings. We are now in a position to begin the crucial tests in 1958.

132. We are also responsible for two of a series of co-operative maize variety trials organized through the Specialist Committee for Agricultural Botany. At Eldoret the earliest variety K8 was wiped out by porcupines; the yields of Kitale Flat White (17½ bags), Nyanza (17 bags), and Hickory King (15½ bags) were significantly greater than the mean of the experiment as a whole, 12 bags per

acre. At Kakamega the differences in yield were not significant, the mean yield for this experiment being about 11 bags per acre.

SORGHUM

D. L. Jennings

133. *Striga Resistance.* The work of breeding for resistance to *Striga hermonthica* and *S. asiatica* commenced with my transfer to Ukiriguru at the end of October, 1956. Previous work at Ukiriguru, by the Senior Botanist of the Department of Agriculture, has established that the variety Dobbs possesses a good level of resistance to *S. hermonthica*; breeding to transfer good quality grains to this variety, has reached an advanced stage. During November, 1956, 258 head selections from this material were planted in replicated trials on land infested with *S. hermonthica*. The sorghum was widely spaced to facilitate counts of Striga plants and more Striga seed was also placed below the sorghum seed at planting time. Initial growth was good, but the plants were almost completely destroyed by a heavy army-worm attack in December, and were subsequently subjected to flooding, so that it is feared that little information on Striga resistance will be obtained. Sufficient seed was available from 45 of the heads to permit a concurrent trial to be planted on land infested with *S. asiatica*. This trial is making good growth but no Striga plants have appeared yet. A further series of selections with good grain have been taken for testing next year.

134. Records of Striga counts on Dobbs and on susceptible varieties are available for a number of years and have been examined from the point of view of obtaining a reliable method of assessing resistance. In some years the numbers of Striga appearing on Dobbs has been equal to the numbers on a susceptible variety, while in other years the number of Striga on the susceptible has been as much as seven times that on Dobbs. The relative number of above-ground Striga plants is therefore not always a reliable indication of resistance. However, the effect of Striga on the plant, as assessed by the difference in vigour and yield on infested and non-infested land, is only occasionally serious for Dobbs but invariably so far susceptible varieties. It is probable therefore that resistance can be assessed if both yield and Striga plant numbers are taken into account.

135. Because of this difficulty, the possibility of substituting a laboratory or greenhouse method of assessing resistance is being investigated. In experiments so far carried out no difference in power to stimulate germination of Striga seed has been detected between solutions prepared from the root exudate from Dobbs seedlings and that from seedlings of susceptible varieties. Further experiments are necessary to determine the dilution end point of these solutions. A more probable explanation of resistance is that the host roots offer a resistance to the haustoria of the parasite; material has therefore been collected for a microscopic investigation of host-parasite relationships.

136. *Antherigona indica* (*Shoot Fly*). The variety Dobbs is resistant to Antherigona attack and records of the intensity of attack are being made on the Dobbs progenies to see if this resistance is related to Striga resistance.

137. *Grain Smut* (*Sphacelotheca sorghii*). Three field experiments have been planted to assess the smut resistance of sorghum material believed to be resistant, and also to find a reliable method of obtaining a high proportion of smutted plants in susceptible varieties. Both wet and dry sorghum seed was dusted with spores in the ratio of approximately 100:1. The experiments were then planted on the poorest soils available and the seed was planted at depths up to 5 inches to see if the susceptible pre-emergence stage could be prolonged. The effect of deep planting on the rate of emergence was not consistent and in two of the experiments the proportion of smutted heads in the susceptible variety was very low or nil. Results from the third experiment are not yet available.

THE AMERICAN RUST DISEASE OF MAIZE CAUSED BY *PUCCINIA POLYSORA* UNDERW.

H. H. Storey and A. K. Howland (*Ryland*)

138. During the period the first phase in the genetical studies of maize for resistance factors has been concluded. The history of this research was reviewed in the 1956 Annual Report, where it was explained that factors for resistance had been found during 1953 in maize types imported from the Central American region, and that this had enabled E.A.A.F.R.O. to distribute to the plant breeders not only seed of maize carrying resistance factors but also information on their inheritance to guide the breeding procedure.

Genetical studies were continued at E.A.A.F.R.O. to confirm and expand this preliminary information and these have now been completed.

139. The first section of a report on our genetical studies was published in *Heredity* (Vol. II (3), Dec. 1957). Two major genes for resistance, designated Rpp_1 and Rpp_2, have been recognized: the former confers high resistance—effectively field immunity—against the rust race prevalent in East Africa, EA. 1, but no resistance at all against a second race, EA. 2. This second race has so far been recognized only in the Muguga glasshouses and it is reasonably certain that it is not yet present at the breeding stations. If it should become prevalent in the field, maize carrying Rpp_1 only would fail. But the gene Rpp_2 confers a lesser, but effective, resistance against both known rust races. The maize breeders have been careful to produce different lines carrying each of these genes. It remains to be seen whether in practice the near immunity of Rpp_1 against one race of the fungus will outbalance the slightly less, but more comprehensive, resistance of Rpp_2.

140. A second paper is being prepared on studies of the relation between Rpp_1 and Rpp_2. These have shown that the two genes are linked but that cross-over occurs in about 12 per cent of the gametes. As a consequence it has not been a straightforward problem to combine both genes in the pure state in a single maize family. This, however, has been achieved by selecting and breeding from cross-over types and we now possess several such families. The plants of these families possess the advantages of both genes: with race EA. 1, Rpp_1 gives them immunity, and with EA. 2—against which Rpp_1 is ineffective—Rpp_2 takes charge and gives resistance. Theoretically, therefore, we are now in a position to transfer both genes together into any chosen maize variety; but field breeding to achieve this would encounter many practical difficulties.

141. The progress in breeding resistant maizes for distribution in areas affected by *P. polysora* has been recorded in a joint paper shortly to appear in the *Empire Journal of Experimental Agriculture*. Here we need only report what we have said in earlier Annual Reports, that the Departmental breeders with whom we have co-operated have made rapid progress and that large quantities of resistant seed will soon be available.

142. It is hoped that we shall never be required to embark on the second phase. This would be necessary if new races of

P. polysora appeared in the field, capable of overcoming the resistance conferred by Rpp_1 and Rpp_2. In order, however to be ready to meet this situation, we must maintain our maize lines and our rust cultures at Muguga; and during the past year we have bred pure lines from most of the imported types showing any resistance to the rust races we have. We may find in these maizes genes for resistance to new rust races.

143. We have, in fact, evidence that a third gene exists in certain maize lines obtained from N. America. Against our present two rust races this gene confers only very moderate resistance, and it is clearly inferior to either Rpp_1 or Rpp_2. Because, however, of its possible future usefulness, we have continued to study the genetics of this supposed third gene. Pure lines reacting uniformly have been readily obtained; but results from crossing these with susceptible maizes, and with lines carrying Rpp_1 and Rpp_2, are difficult to interpret and the genetical picture is uncertain.

THE GENETICS OF RESISTANCE IN MAIZE TO THE VIRUS OF STREAK DISEASE

H. H. Storey and A. K. Howland

144. This research has been incorporated into the programme at Muguga. Streak is a virus disease that at some sites and in some years can be extremely damaging to maize; and resistant types would be a valuable asset.

145. Breeding studies had been started in 1939–41 at Amani, based on resistant material from a variety Peruvian Yellow selected by workers at Barberton in South Africa. War had brought this work to a standstill; but in recent years Mr. Doughty recovered resistance in the old material. He continued breeding at Eldoret, where, however, facilities were limited and many practical difficulties were encountered. It was agreed that the work be continued in the glasshouses at Muguga.

146. The only known means for transferring the streak virus from one maize plant to another is through the agency of its insect vector, a leafhopper *Cicadulina mbila* (Naude). For testing maize progenies it is therefore necessary to have large numbers of this insect. It is a species that does not breed freely unless given suitable conditions (which, however, are not yet fully known). We

have still to find the ideal conditions at Muguga and we lack the full numbers of insects that we need.

147. However, a start has been made in testing maize lines handed to us by Mr. Doughty. The basis for genetical studies has been laid, for several apparently immune plants, and many highly resistant ones, have appeared in some of his progenies. From these, pure lines and crosses will be bred to obtain evidence on the genetical control of resistance.

VIRUS DISEASES OF SWEET POTATOES

F. M. L. Sheffield

148. During the period under review this study was concluded. In previous years, two viruses attacking Sweet potato in East Africa had been identified. Virus A, carried by aphids, caused only mild diseases and was found only near Moshi. Virus B, transmitted by white flies, was widespread and existed in several strains, some of which caused very severe diseases. Neither virus was transmitted mechanically to Sweet potato; but virus B was, with difficulty, transmitted by this method to some other hosts even when the inoculum was taken from Sweet potato.

149. Virus A was transmitted by grafting or by insects to several *Ipomoea* spp. but not by insects to tomato or tobacco and not mechanically to *Ipomoea* spp., *Petunia* sp. or to *Gomphrena globosa.* As virus B is far more important than virus A, attention was focused chiefly on it. The plant species tested for their susceptibility to it included related species, common weeds, some of the usual virus test plants and hosts of viruses known to be carried by white flies.

150. Systemic infection with virus B occurred in *Ipomoea alba, I. daysperma, I. fistulosa, I. garckeana, I. purpurea,* in a cultivated sp. near to *I. purpurea* and in *Mina lobata,* but not in *Merrimeria tridentata.* Some of these were severely affected whilst others were almost symptomless. In tomato and in *Physalis peruviana,* virus B caused very mild diseases; in *Nicotiana tabacum, Datura ferox* and *Petunia* sp., it caused severe, and in *Nicotiana glutinosa* very severe, disease. *Gomphrena globosa* was the only host found in which the virus was confined to local lesions. Naturally infected plants of *Ipomoea leari* and *Physalis peruviana* possibly carried virus B.

151. I failed to infect with virus B: *Chenopodium amaranticolor, Bidens pilosa, Veronia* sp., *Zinnia* sp., *Abutilon* sp. and hybrids, *Gossypium* sp. and *Hibiscus esculentus*. I also failed to infect cassava with virus B, or Sweet potato with cassava mosaic virus.

152. Although some species of *Ipomoea* seemed tolerant of virus B, no immune species was found.

153. Virus diseases of Sweet potato have been recorded from several countries but only in the United States of America have any been examined in detail. These were all transmitted by aphids; but it is not possible to identify virus A with any of them.

154. Virus B is distinguished from them by its insect vector. Viruses known to be transmitted by white fly are few in number. Experiment failed to identify virus B with cassava mosaic, and its host range differs from that of the virus causing mosaic of *Euphorbia prunifolia*. Several viruses attack malvaceous plants, but virus B failed to infect several known hosts of these. Symptoms of virus B in tobacco were quite different from those of leaf curl, which is carried by *Bemisia* sp.; and *Veronia* sp., thought to be a host of leaf curl, seems immune from virus B. The white-fly-transmitted viruses of legumes and curcurbits are not sap-transmissible. It must therefore be concluded that virus B is distinct from any white-fly-transmitted virus previously recorded.

155. Two papers describing the above work have been accepted for publication in the journal *Phytopathology*.

SUGAR CANE PATHOLOGY

F. M. L. Sheffield

156. The Ratoon-stunting disease has come to be recognized as a major problem in East African sugar production. It is a difficult disease to recognize, for, apart from certain not very reliable colour changes in the stem, its only known effect is a general reduction in growth. Because there is now conclusive evidence that it is widespread in East Africa, I prepared a summary of the known facts concerning it, to assist agricultural officers and others working with sugar cane. This was published in the *E.A. Agricultural Journal*.

157. In connexion with the work of the Quarantine Station, sugar cane setts have been treated with hot water on a time and temperature schedule found in other countries to be effective in eliminating the virus of Ratoon stunting. Visits have been paid to Nyanza Province of Kenya and to Uganda, for discussions on the symptoms and effects of this disease and on measures necessary for its control.

158. Meanwhile research on certain obscure features of Ratoon stunting has been started at Muguga. I paid a visit to the Union of South Africa in September, 1957, especially to learn the latest advances there in sugar cane pathology; and during a week spent at Mt. Edgecombe, Natal, I was kindly received and shown not only the research in progress but also several diseases in the field that have not been recorded in East Africa. This visit did much to enhance the co-operation that already exists between the Natal Station and E.A.A.F.R.O.

ECOLOGY

C. G. Trapnell

THE EFFECTS OF FIRE IN BRACHYSTEGIA-ISOBERLINIA WOODLANDS (NORTHERN RHODESIA)

159. The influence of fire on the *Brachystegia-Isoberlinia* woodlands known as Miombo is an issue of wide consequence in East Africa. They have frequently been held to represent a fire sub-climax, i.e. to maintain their dominance by virtue of the periodic grass fires to which they are subject. Burning experiments in these woodlands have been maintained continuously by the Northern Rhodesia Forest Department at Ndola since 1933, the three treatments being a late or hot burn at the end of the dry season, an early or cool burn, and complete protection. The treatments were applied both to standing woodland and to regeneration after clear felling. Facilities for revisiting these plots were provided by the Northern Rhodesian Forest Department at the end of 1956, which made it possible to determine, on experimental evidence, the fire reactions of at least 30 species of trees and shrubs in the woodlands, with probable indications in the case of a number of other species.

160. Contrary to accepted beliefs the main canopy dominants of the genera *Brachystegia* and *Isoberlinia* were found to be fire-tender, the species involved being *Brachystegia spiciformis, B. longifolia, Isoberlinia paniculata,* and *I. tomentosa.* Full fire-tolerance was established in the case of only three of the canopy associates, *Parinari curatellifolia, Erythrophloeum africanum* and *Pterocarpus angolensis.* On the other hand the understorey and small tree and shrub components were shown to contain a large number of tolerant or semi-tolerant species. In the area of the experiments the lower layers are invaded by a variety of evergreens, largely lianes, as a result of complete protection, but there is as yet no evidence of evergreen emergence at canopy level. In general it would seem that these woodlands can be regarded as a fire-induced type only in respect of their lower-layer components and they can in fact be destroyed by sufficiently repeated late burning.

161. The effects of these treatments on the topsoil of the woodland plots were also investigated by the Chemistry Division.

The pH, exchangeable bases and phosphate status were raised by the burning treatments, compared with the protected plots, and this was more marked in the late burnt ones. Exchangeable calcium was highest under late burning, owing probably to the relatively high content of calcium in the wood ash of this region; whilst exchangeable potassium was slightly higher with early burning, owing probably to the higher potassium content of grass ash. On the other hand these two burning treatments had no effect on the organic matter or organic nitrogen content of the surface soil, which was probably a consequence of termite activity in the early burnt and protected plots. However, burning, and repeated late burning in particular, increase the liability of the surface soil to erosion in regions with a torrential one-season rainfall owing to the destruction of the ground vegetative cover.

CLIMATIC TYPES OF VEGETATION IN SOUTHERN KENYA

162. A major field reconnaissance has been carried out of the vegetation types of the Nyanza, Southern and Rift Valley Provinces and of part of the Central Province of Kenya south of Lat. 1°N. The purpose of this is to obtain an overall classification of the climatic types of vegetation through the main region of agricultural potential, so as to co-ordinate the ecological zones which have been determined in the several provinces by members of the Agricultural Department. The initial field-work has involved traverse records, with aneroid observations, over all major and many minor routes in co-operation with Agricultural Officers of the districts concerned. Correlation of the vegetation types with climatic data and their grouping into zones suitable for land-use purposes is to follow.

163. The range of vegetation types found in this block of country is remarkable and considerably greater than previous publications indicate. Previously insufficiently recognized types include semi-evergreen thicket and thicket-forest types towards the Lake Victoria shore and various evergreen and semi-evergreen thicket, scrub and scrub-grassland types fringing the forest region of the central highlands. In order to break down the secondary vegetation types of the populous higher rainfall areas it has also been necessary to go into the evidence for the forest types from which they have been derived. A noteworthy point which has emerged is the contrast between the sequences of vegetation types

found in the Lake Victoria region and those of the region to the east of it. The division may be roughly delineated by a line from the southern flanks of Mount Elgon, enclosing Kitale but passing west of Eldoret and thence south through the western portions of the Tinderet and Mau forests and along the western side of the Chepalungu forest. The "Nandi Thorn" belts between Kapsabet and Sotik lie on this division. Broadly speaking to the west of this line the vegetation-sequence has affinities with the vegetation types of Uganda, in contrast to the more characteristic Kenya complex to the east. Certain types, such as *Combretum* savanna, occur on either side, but in these cases there are commonly differences in floristic make-up. Very different combinations of temperature, rainfall and humidity are, of course, involved.

164. In certain areas, as a sequel to alterations of the original vegetation cover resulting from human occupation, there have been major encroachments of tussock grasses, thorn or Lileshwa scrub. Of the tussock grasses *Cymbopogon afronardus* and, more locally, *Pennisetum catabasis* are of consequence in heavily cultivated and grazed areas in Nyanza Province. The *Cymbopogon* particularly requires study in view of its widespread increase in grazing lands in Uganda. Thorn-scrub encroachment, involving several *Acacia* species is found in various areas, commonly as an invasion into country formerly occupied by a less arid type of vegetation. This has happened, for example with *Acacia drepanolobium* in Nanyuki. Mass colonizations by juvenile *Acacia hockii* (formerly *A. seyal* var. *multijuga*) have appeared in several areas, e.g. near Eldoret and in Machakos. Full-sized trees of this species are seldom seen, and the indications are that it is spreading, particularly in former *Combretum* areas.

165. Most serious in Kenya, however, has been the march of Lileshwa (*Tarchonanthus camphoratus*), which may originally have been a restricted marginal species of the drier edges of evergreen or semi-evergreen scrub belts. It has made formidable gains under the combined influence of the Masai policy of burning to extend grazing into evergreen scrub and forest country and of overgrazing in the grasslands behind. The great tracts which it now occupies in the lower Rift and Narok regions are only too clear from the air, but the threat held by its outlying colonies in areas such as Laikipia is not generally realized. Studies made of its associates indicate that large areas of valuable grazing land are still awaiting the invasion, and prevention of its further spread is widely needed.

166. The distribution of major vegetation types in Kenya, although subject to soil factors, is primarily controlled by climate, and the first objective, therefore, has been the determination of climatic zones of vegetation. From a land-use point of view, however, the ultimately desirable unit of classification may be considered to be the vegetation—soil unit—that is to say, a land unit which is uniform in respect both of its vegetation category and of its soil class as determined by field characteristics. Such a combined unit covers both the climatic and soil aspects of land potential. This approach is the more relevant here in that several major soil classes in Kenya show little correlation with the present climatic pattern.

167. This point may be illustrated by the tropical black clays, which were the subject of special comment by the Soil Survey Division in the previous Report. If these soils are considered in their full range, from the black hill clays with lighter-coloured subsoils on steeper volcanic elevations to the extensive black clay plains surrounding the volcanic region, they occur in their extremes from very moist *Aningeria* forest in Tinderet to desert vegetation in Turkana, through a whole series of differing combinations of rainfall and altitude. While, of course, they vary chemically over this very wide distribution and admit of subdivision, a working unit for land classification can be obtained by combining their pedological designation with the vegetation type found upon them. Such units are readily mapped, and in a country as varied as Kenya much would be gained if all results of land-use investigations and experimental work were so documented, so as to place them in their appropriate context.

STRUCTURAL CHARACTERS OF SOILS OF THE RED EARTH ORDER

168. Extensive field observations made in the course of the Ecological Training Scheme brought to light marked structural differences in the profiles of soils of the red earth order and of allied soils which may be referred to for convenience as yellow earths. It was subsequently found that these differences could be traced to characteristic micro-structures which become visible in the moistened soil under the low-power microscope. With the help of the large profile collection made by the Soil Survey Division, and with supplementary collectings from various areas, sufficient material has now been examined for an outline morphological

classification covering a wide geographical range. The structure of the topsoil is subject to modification by organic matter, and determinations have therefore been made on material from below the limit of humic discoloration. Samples have been examined by two methods, gradual moistening by imbibition without surface wetting, and sudden wetting which produces a distinct "artificial" structure or structural breakdown. Any soil, of course, provided it has a sufficient clay-fraction, may contain a combination of larger and smaller aggregates. Classification has been based on the smallest aggregates found in the loose soil, but larger aggregates have also to be taken into consideration.

169. All material of these soils so far examined falls into one of three major categories, a markedly angular or fragmental structure, resulting seemingly from simple fragmentation of the soil mass, a minutely granular structure involving more or less spherical colloidal bodies, either discrete or in compound aggregates, and an intermediate group comprising more than one type falling between these two extremes. The profile in the first class is homogeneous in the sense that the whole soil body below the humic horizon is composed of larger or small fragmental aggregates. The profile at the opposite extreme is dual-structured, being composed of a combination of minutely granular aggregates with large pellet-like bodies which lack this micro-structure. Comparable larger bodies also occur in the intermediate categories. These pellet structures are commonly soft in the fresh soil but harden off on exposure. The first category, the fragmental soils, approximates to the "angular blocky" type of American terminology. The minutely granular structures, however, fall below the size-limits of the American classification, and the soils possessing them, being dual-structured, have been subject to very varying designations in profile descriptions according as the pellet aggregates or the finer soil fraction have attracted more attention.

170. For purposes of classification the natural micro-structure is considered to be that attained on gradual absorption of moisture. The effect of this is to reproduce the "live" cells of the soil body as against their dried and shrunken tissues. At the same time more than a simple morphological classification is involved. There are, in the first place, very evident differences in the cohesiveness of the finer structures following absorption of moisture, an aspect which is receiving further attention. Secondly, if instead of gradual moistening, the dry soil is subjected to sudden wetting, marked differences in structural stability become apparent. The fragmental

types, for example, break down rapidly into sharply angular smaller fragments with accommodating faces, and the process of comminution can be repeated by successive drying and wetting. The minutely granular class includes highly unstable types which undergo an instantaneous collapse into much smaller fragments, types which are subject to partial disintegration only, and a type in which the smaller granules are fully water-stable. These differences in stability have been found in the subsoil, not in the upper humic horizons.

171. A large series of colour micro-photographs of the various structural types has been prepared by P. R. Hesse, covering both conditions of moistening, and it is hoped to complete the morphological description in the near future with the citation of a range of type profiles. Determination of the factors involved will require fuller studies of individual profiles, with references particularly to the conditions associated with granulation. Differences in physical properties may also be expected.

MISCELLANEOUS STUDIES

172. Other work involving vegetation-soil relations has included a revision of an earlier publication in this field requested by the Northern Rhodesian Agricultural Department. Field investigations have included examinations of the grassland problems of the western portion of the Royal Tsavo National Park and of the Queen Elizabeth National Park. The latter area has been subject to severe overgrazing by a very large hippo population, and a scheme for trials in the control of grazing movements has been put forward.

SYSTEMATIC BOTANY

THE WORK OF THE EAST AFRICAN HERBARIUM

P. J. Greenway, B. Verdcourt and D. M. Napper

173. During the 18 months under review the amalgamation of the Coryndon Museum Herbarium was completed. Close collaboration has continued with the Herbarium staff of the Royal Botanic Gardens, Kew, and Messrs. E. Milne-Redhead and P. Taylor from there used the Herbarium as a base during a nine-month collecting trip through Tanganyika and around Songea which they made in connexion with their work on the Flora of Tropical East Africa.

174. Samwell Paulo, from the Herbarium was loaned to help them in collecting botanical specimens and looking after the proper drying of the material collected.

175. Use was also made of the Herbarium by Mr. A. V. Bogdan, Grassland Research Station, Kitale; by Mr. I. R. Dale in the preparation of his book *Trees and Shrubs of Kenya Colony*; by Miss M. E. Griffiths, Agricultural Research Station, Kawanda, Uganda; by Dr. E. M. Lind, Department of Botany, Makerere College; by Prof. R. E. Pichi-Sermolli, Instituto Botanico, Universitatis Florentinae, Florence, Italy; by Dr. H. W. E. Croockewit, Amsterdam Zoological Museum, Amsterdam, Holland; by Dr. B. L. Turner, Botany Department, University of Texas, Austin, Texas, U.S.A., and Dr. H. L. Shantz, Santa Barbara, California, U.S.A., part author of *The Soils and Vegetation of Africa.*

176. Four hundred and ninety-five accessions of botanical material were received comprising over 9,500 for naming, 4,200 named and received in exchange, and over 1,800 loaned for study.

177. Of the collections received for naming the following are the more important:—

Belgian Congo: Institut pour le Recherche Scientifique en Afrique Centrale, 367, Dr. G. Troupin.

Eritrea: Desert Locust Survey, 154, Mr. C. F. Hemming.

Ethiopia: Desert Locust Survey, 96, Messrs. C. Ashall, J. W. Simmons; Jimma Agricultural and Technical School, 81, Messrs. R. B. Stewart and I. E. Siengenthler; the F.A.O. Mission, 13, Mr. H. P. Huffnagel.

Kenya: Administration, 25, Mr. L. Nottingham; African Explosives, 16, Mr. Sherwood; Agriculture Department, 85, Messrs. D. Bell, J. MacDonald, Le Pelly, J. C. Templer and Mrs. Nattrass; The Coryndon Memorial Museum, 438, Messrs. P. R. O. Bally and J. G. Williams; E.A.A. & F.R.O., 175, Messrs. A. L. Griffith, P. Howland, W. May, J. Quarterman, C. G. Trapnell, A. G. Whitehead and Dr. F. M. L. Sheffield; E.A. Herbarium, 918, Miss Napper, Messrs. P. J. Greenway, Kanure, E. P. Kirrika, H. Padwa, J. Semlingwa, and B. Verdcourt; E.A. Meteorological Department, 5, Mr. F. Grundy; E.A.V.R.O., 9, Messrs. S. Barnett and Fleetwood; The Education Department, 116, Messrs. Jarlock Nath, M. Singh, A. B. Shasma and the Duke of Gloucester School; Forest Department, 801, Messrs. Argyle, R. F. Board, W. G. Dyson, H. H. Pudden, S. Rawlins and J. B. Smart; Game Department, 134, Mrs. J. Adamson and Mr. P. J. Whitehead; Government Chemist, 7; Messrs. Grahame Bell, 56; Grassland Research Station, 153, Messrs. A. V. Bogdan, R. M. Edmondson and J. D. Knight; High Level Sisal Research Station, 67, Mr. M. B. Sanders; Fisons Pest Control, 146, Mr. C. van Someren; The Pyrethrum Research Station, 46; Royal Gedi National Park, 9, Mr. T. Adamson; Royal Technical College, 50, Mr. Coe; Veterinary Department, 210, Messrs. Jarrett, Langridge, Parsons, D. J. Pratt, D. B. Thomas and E. C. Trump and sundry private collectors 1,289 specimens, Mrs. Bickford, 41; Mr. I. R. Dale, 24; Mrs. Hume, 131; Miss J. Hyde, 107; Mrs. D. Irwin, 124; Mrs. F. Klotzli, 240; Mr. R. S. Lindsay, 100; Col. R. Meinertzhagen, 61; Miss J. Ossent, 134; Mr. P. J. R. Sanders, 92; Mrs. A. W. Symes, 195; and Messrs. H. D. and V. G. L. van Someren, 40 specimens.

Northern Rhodesia: St. Mark's College, 32, Mr. E. A. Robinson.

Somaliland: Desert Locust Survey, 76, Messrs. G. Popov and C. F. Hemming.

South Africa: National Herbarium, Division of Botany, Pretoria, 37 specimens.

Tanganyika: Administration, 3, Mr. H. Elliott; Agricultural Department, 126, Messrs. M. Cole, H. J. de Disney, G. C. Platt, S. D. Pyman and H. Sanders; The Agricultural Corporation, 37, Mr. B. Anderson; Colonial Pesticides Research, 267, Dr. G. W. Ivens; E.A.A.F.R.O., 34, Mr. A. G. Whitehead; E.A. Herbarium, 272, Messrs. P. J. Greenway, S. Paulo, B. Verdcourt and G. Williams; E.A. Malaria Unit, 1, Dr. B. Wilson; E.A.T.T.R.O., 50, J. Welch; Forest Department, 1,074, Messrs. J. M. Bryce, W. Carmichael, Foster, Mgaza, M. S. Parry, Procter, S. Semsei, F. G. Smith, R. L. Willan; Game Department, 21, Messrs. D. B. Nicholson and H. F. Lamprey; Government Chemist, 33; Sisal Research Station, 67, Messrs. H. Sandford and G. W. Lock; Veterinary Deparment, 53, T. O. Robson, J. H. van Rensburg and G. D. Scott; Water Development, 67, Mr. T. W. Dames and sundry private collectors, 35 specimens.

Uganda: Agricultural Department, 307, Messrs. D. F. Chenery, C. R. Horrell, I. Langdale-Brown, J. Wilson; Animal Health Research Centre, 454, Messrs. K. W. Harker and D. D. Thornton; Makerere College, Department of Botany, 144, Dr. E. M. Lind, Miss A. C. Tallantire and Mr. C. Sanderson; Game and Fisheries Department, 294, Messrs. A. C. Brooke, H. K. Beuchner, J. D. Roberts and G. Petrides; Forest Department, 70, Mr. H. C. Dawkins and other collectors; Dr. R. Y. Stones and other private collectors, 147 specimens.

U.S.A.: College of Medical Evangelists, Loma Linda, California, 116, Mr. R. M. Ritland; Ohio State University, 14, Mr. D. C. Rife; University of Texas, 30, Drs. Santz and B. L. Turner.

Zanzibar: Clove Growers Association, 2, Mr. R. O. Williams.

178. The named specimens were in exchange and were received from:—

Belgian Congo, I.N.E.A.C., Yangambi, 100 specimens; *Belgium*, Jardin Botanique de L'Etat, Brussels, 436 specimens; *England*, Imperial Forestry Institute, Oxford, 117 specimens; Royal Botanic Gardens, Kew, 1,636 specimens and 40 photographs of types; *South Africa*, National Herbarium, Division of Botany, Pretoria, 152 specimens; Dr. G. W. Reynolds, 20 specimens of *Aloe* types and 45 photos of Aloes; *Sweden*, Institute of Systematic Botany, University of Uppsala, 863, all collected by Dr. O. Hedberg in the course of his vegetation survey of the alpine zone of the East African mountains.

179. Over 14,700 items were distributed. These included the loan of herbarium sheets for study to:—

England, the British Museum (Natural History), 28 ciné stills of members of the Angolan Flora; the Royal Botanic Gardens, Kew, 3,763 specimens including 1,328 Caesalpiniaceae, 983 Mimosaceae, 127 Papilionaceae, 43 Droseraceae, 592 Rosaceae, 328 *Lantana* and *Lippia,* 109 ferns, all for the study of the Floras of Tropical East Africa and Zambesiaca and 253 miscellaneous specimens; Mr. Allen, Godalming, Surrey, 23 charophytes; *Germany,* Berlin Botanic Gardens and Museums, 130 marine algae; Botanische Staatssammlun, München, 126 *Limeum, Berkheya* and *Berkheyopsis*; *Portugal,* Botanical Institute of the University of Coimbra, 174 *Memecylon; South Africa,* National Herbarium, Department of Botany, Pretoria, 26 miscellaneous; Witwatersrand University, East African Economic Uses Index Cards A–C; *Uganda,* Department of Agriculture, Kawanda, 56 Terminalia spp. for Miss Griffiths to study and determine; Makerere College, East African Economic Uses Index Cards A and B; *U.S.A.,* Missouri Botanical Garden, St. Louis, 13 lichens; Wabash College, Indiana, 22 Hernandiaceae; Herbarium of the University of Wisconsin, 33 *Carapa* and *Xylocarpus.*

180. Named duplicate specimens in exchange or presented were sent to:—

Belgian Congo, I.N.E.A.C., Yangambi, 100 miscellaneous; *Belgium,* I.N.E.A.C., Brussels, 3 *Julbernardia;* Jardin Botanique de l'Etat, 375 miscellaneous; *England.* The British Museum (Natural History), 225 specimens; the Royal Botanic Gardens, Kew, 4,261 specimens; the Imperial Forestry Institute, Oxford, 1,833, mostly Tanganyika; *Germany,* Berlin Botanic Gardens and Museums, 151 specimens; *South Africa,* Kirstenbosch National Botanic Gardens, 40 specimens; National Herbarium, Division of Botany, Pretoria, 441 specimens; *Southern Rhodesia,* Government Herbarium, Salisbury, 56 Southern Africa specimens; *Sweden,* Institute of Systematic Botany, University of Uppsala, 153 East African specimens; *U.S.A.,* Missouri Botanical Garden, St. Louis, and the Herbarium of the University of Utah, Salt Lake City, 160 miscellaneous specimens including lichens.

181. Seeds, living plants and plant material totalling over 230 items were sent to the following:—

England, Cambridge Botanic Gardens, two seeds of *Delphinium* and *Ricinus;* Colonial Products Research Council, six items of *Cissus, Fagara, Hagenia* and *Rauvolfia* for chemical examination; Royal Botanic Gardens, Kew, 58 items consisting of spirit material, seeds and living plants of *Acacia,* Aloes, Convolvulaceae, *Crotalaria* spp. *Dorstenia, Encephalartos, Euphorbia, Notonia, Saintpaulia,* etc., for cultivation and study; *Holland,* Rijksherbarium, Leiden, *Adenium* sp.; *India,* Calcutta University, seeds of 13 *Corchorus* spp. for genetical studies; *Scotland,* The University, Glasgow, bulk quantities of *Acokanthera friesiorum* and *A. longifolia* for chemical examination; *South Africa,* Kirstenbosch National Botanic Gardens, seeds of *Encephalartos;* National Herbarium, Division of Botany, Pretoria, 24 items consisting of seeds and living plants of *Aloe, Dorstenia, Encephalartos, Euphorbia, Heywoodia, Notonia,* etc., for cultivation and study; Dr. G. W. Reynolds, plants of nine *Aloe* spp. for cultivation in connexion with his studies of Tropical African Aloes; Witwatersrand University, seeds of *Ricinus; Sweden,* Dr. Erdtmann, Palynological Laboratory, Bromma, Stockholm, 70 pollen samples; *U.S.A.,* The Bailey Hortorium, Cornell University, Ithaca; Indiana University, Bloomington; New York Botanical Garden and others, 11 items of seeds, spirit and plant material of *Bophane, Chrysalidocarpus, Delphinium macrocentron, Monodora myristica* and *Solanum nakurensis,* etc., for botanical and chemical investigations.

182. In addition help was given to Government departments and private individuals by the loan of botanical presses, mounting and drying papers, books and pamphlets and a MS. map showing the main vegetation types of Eastern Africa was loaned to Mr. Rattray of the F.A.O. of the U.N. Rome, in preparation of a Grassland Map of Africa.

183. The following new species have been described from the herbarium:—

Bertiera pauloi Verdcourt (Rubiaceae) in *Kew Bull.*, 1957, p. 352.
Paulo 224! Holotype.

Bidens grantii (Oliv.) Sherff var. *stapfioides* Sherff (Compositae), lc. 1956, p. 445.
Smith 1134! Holotype.

Bussea eggelingii Verdcourt (Caesalpiniaceae) lc. 1957, p. 350.
Eggeling 6396! Holotype.

Convolvulus jefferyi Verdcourt (Convolvulacaeae) lc., p. 344.
Jeffery 749! Holotype.

Cordia sukertii Chiov. var. *exasperata* Verdcourt (Boraginaceae) lc., p. 333.
Popov 1029! Holotype.

Coreopsis odora Sherff (Compositae) lc., 1956, p. 445.
Semsei 1655! Holotype.

Cola greenwayi Brenan var. *greenwayi* Brenan (Sterculiaceae) lc., p. 144.
Greenway 7891! Isotype.

C. greenwayi var. *keniensis* Brenan, lc., p. 146.
Gardner 1193! Isotype.

C. microcarpa Brenan, lc., p. 147.
Semsei 1466! Isotype.

C. minor Brenan, lc., p. 149.
Dale 3786! Isotype.

C. stelechantha Brenan, lc., p. 143.
Paulo 182! Isotype.

Cuviera semseii Verdcourt (Rubiaceae), lc., p. 449.
Semsei 620! Holotype.

Dissotis arborescens A. & R. Fernandes (Melastomaceae) in *Bol. Soc. Brot.* 29, Ser. 2a, p. 51 (1955).
Greenway 6176! Isotype; *Wallace 1321!*

D. caloneura Gilg var. *setosior* A. & R. Fernandes, lc., 30, Ser. 2a, p. 171, t. 5 (1956).
Eggeling 6172! Holotype.

D. denticulata A. & R. Fernandes, lc. 29, Ser. 2a, p. 57 (1955).
Greenway 5765! Holotype.

D. greenwayi A. & R. Fernandes, lc. 30, Ser. 2a, p. 172, t. 8 (1956).
Greenway 8410! Holotype.

Drypetes natalensis (Harv.) Hutch. var. *leiocalyx* Brenan (Euphorbiaceae) in *Mems. N.Y. Bot. Garden* 9, p. 70 (1954).
Greenway 2653! Isotype.

Heinsia bussei Verdcourt (Rubiaceae) in *Kew Bull.*, 1957, p. 353.
Busse 1083a! Holotype.

Hyalocystis popovii Verdcourt (Convolvulaceae) lc., p. 347.
Popov 1122! Holotype.

Lasianthus grandifolius Verdcourt (Rubiaceae) lc., 1956, p. 450.
Eggeling 6472! Holotype.

Lasiodiscus ferrugineus Verdcourt (Rhamnaceae) in *Bull. Jard. Bot. Brux.* 27, p. 362 (1957).
Rawlins 241! Holotype.

Limeum fruticosum Verdcourt (Molluginaceae) in *Kew Bull.*, 1957, p. 351.
Popov 1119! Holotype.

Pavetta aethiopica Brem. (Rubiaceae) lc., 1956, p. 174.
Bally 9397! Isotype.

P. axillipara Brem. lc., p. 171.
Semsei 1451! Isotype.

P. iringensis Brem. lc., p. 175.
Carmichael 290! Isotype.

P. kisarawensis Brem. lc., p. 175.
Paulo 142! Isotype.

P. kimbosensis Brem. lc., p. 176.
Semsei 1398! Isotype.

Rhynchospora minor Nelmes (Cyperaceae) lc., p. 433.
Fitzgerald 5217! Isotype.

Satureja abyssinica (Benth.) Briq. var. *condensata* Hedberg (Labiatae) in Afroalpine Vascular Plants, *Symb. Bot. Upsal.* 15, p. 1 (1957).
Dale 2417! Isotype.

Seddera bracteata Verdcourt (Convolvulaceae) in *Kew Bull.*, 1957, p. 339.
Popov 1075! Holotype.

S. simmonsi Verdcourt, lc., p. 340.
Simmons S156! Holotype.

Sorghum brevicarinatum Snowden var. *swahilorum* Snowden (Gramineae) in *Journ. Linn. Soc. Bot.* 55, p. 245 (1955).
Greenway 1956! Isotype.

S. verticilliflorum (Steud.) Stapf var. *infrequens* Snowden lc., p. 238 (1955).
Thomas 3884! Isotype.

Stathmostelma praetermissum Bullock (Asclepiadaceae) in *Kew Bull.*, 1953, p. 347.
Bally 8380! Isotype.

Tetraorchidium ulugurense Verdcourt (Euphorbiaceae) lc., 1957, p. 347.
Semsei 1435! Isotype.

Tristemma acuminatum A. & R. Fernandes (Melastomaceae) in *Bol. Soc.* Brot. 30, Ser. 2a, p. 184, t. 21–3 (1956).
Greenway 3683! Isotype.

Vernonia perculiaris Verdcourt (Compositae) in *Kew Bull.*, 1956, p. 447.
Hornby 780! Holotype.

V. rhodanthoides Muschler var. *densifolia* Verdcourt lc. 1957, p. 334.
Greenway 5256! Holotype.

These 38 new species together with 38 others and 11 mosses on the Hedberg moss collection brings the total of known types in the Herbarium up to 852.

184. Whilst on the subject of new species, Dr. H. J. de Disney, Zoologist of the Tanganyika Agricultural Department, collected a cotton, both botanical specimens and seeds, which were sent to Sir Joseph Hutchinson of the Empire Cotton Growing Corporation's Research Station at Namulonge. He reported that it was a species new to science and is naming and describing it. Some months later amongst a collection of specimens made by Mr. G. Wilson of the Uganda Agricultural Department in the Moroto area of Karamoja, Uganda, the same cotton was collected by Mr. Wilson thus extending the distributional range of quite a new species from central Tanganyika to north-east Uganda. A strange coincidence that two widely separated people should find the same new species of cotton within a few months of each other, but this, we note, is frequently happening amongst the many interesting collections that are sent to us to name. Quite often a species that appears to be rare in the E.A. Herbarium and other herbaria is soon represented by several sheets from other localities in East Africa.

185. Over 14,100 specimens have been named and information supplied to botanical institutions, Government departments and numerous private individuals not only in East Africa but in the United Kingdom, the Continent, Southern Africa and the United States of America.

186. In addition to this work Dr. Verdcourt completed his MS. of the families Convolvulaceae and Melianthaceae for the Flora of Tropical East Africa.

187. Miss Napper who was on U.K. leave from April till November spent some of her leave working in the Herbarium of the Royal Botanic Gardens, Kew, where she made contacts with various botanists and studied the East African Gramineae there.

188. Over 15,000 named specimens have been filed into the Herbarium and are available for study.

FIELD WORK

189. At Prof. W. H. Pearsall's request Dr. Greenway accompanied him in November–December, 1956, on an ecological survey of the Ngorongoro Crater and Serengeti Plains, Tanganyika, in connexion with the future of this National Park and Government's policy and intentions as regards this area. In spite of the drought conditions prevailing at the time some 150 specimens in

quadruplicate were collected as well as a number of molluscs for Dr. Verdcourt. In June, he was accompanied by Dr. E. M. Lind, Botany Department, Makerere College, Kampala, Uganda, on a quick three days' visit to the Royal National Park at Amboseli and the area Namanga to Longido. The vegetation of this semi-desert area was just at its optimum and three plants new to science were collected as well as an Asiatic species that was hitherto only recorded in Africa from Egypt. From the end of September to mid-November, 1957, he travelled in the Garissa, Lamu, Witu, Kipini Districts of Kenya returning by way of Garsen, Malindi, Mombasa–Nairobi. Over 280 specimens in quadruplicate including about 60 seaweeds were collected. This collection has not yet been named but there should be many new records for the seaweeds, and it is known that there is in the collection at least one grass, if not two, new to science, a Pontederiaceae hitherto not recorded from East Africa, also *Salvinia hastata,* from the Boni Forest previously only known as far north as southern Tanganyika, a new Monadenium from Mlango ya Simba just north of Garsen. He has also done casual collecting during week-ends and bank holiday periods in the area of Rongai Ranches on the western footslopes of Kilimanjaro, Ngong Hills, and Orgasaile–Magadi.

190. Dr. Verdcourt collected in and around the Ngorongoro Crater, Tanganyika, in August, 1956, and in the Mitito Andei area in November. In December he made a flying visit to Kakamega Forest, and he spent a local leave period in the Usambara Mountains, Tanganyika, visiting for collecting purposes Amani and Shume. In August, 1957, he paid a short visit to Marsabit, and in September, in the company of members of the Coryndon Museum staff, he visited Mrima Hill. He has also done casual collecting during week-ends during visits to Narok, Kinangop, Ngong Hills, Orgasaile, Magadi, Thika, Muguga and elsewhere, and collected over 400 specimens in quadruplicate or more. From the material he has brought back it is quite evident that a botanist could be very profitably employed collecting assiduously in the Kakamega Forest and in the remnant forest on and around Mrima Hill, as amongst Dr. Verdcourt's material there was quite a surprising number of plants from these two places that, hitherto, had not been recorded from Kenya.

ANIMAL NUTRITION DIVISION

CHEMICAL COMPOSITION OF GRASSES GROWN AT MUGUGA

J. Quarterman

191. Several local grasses have been analysed for their main organic components at regular intervals of continuous growth throughout one year. The results were compared with those published for temperate area grasses, and where differences were found the investigation was made in more detail. The grasses chosen were Rhodes grass (*Chloris gayana*), Elephant grass (*Pennisetum purpureum*), Kikuyu grass (*P. clandestinum*), Star grass (*Cynodon dactylon*), Couch grass (*Digitaria scalarum*) and *Eragrostis tenuifolia*, and the legume was *Idigofera endecaphylla* Jaqu. The analyses were made at fortnightly intervals for protein (crude and true), cellulose, lignin, xylan and crude fibre.

192. The nutritive value of these grasses grown at Muguga are comparatively very good as judged from their chemical analyses. The *Eragrostis* has the lowest lignin in fibre and the highest protein content, and should therefore be the best grass, but this annual is generally unpalatable and gives such a low yield that it is properly regarded as a weed. Of the other grasses Kikuyu has quite the best analysis at all stages of growth, followed by Elephant and Rhodes grass which are very similar, and then Star grass. The Couch grass is good for the first month and a half of its growth, but after that becomes the most fibrous and has the lowest protein content of all these grasses. Naturally this order of quality is not necessarily that of their value as grazing in the field, because it takes no account of the yield of the grass, particularly yield at different periods of the year. Thus, although Star grass comes lower in the order of quality, it is one of the most useful grasses at Muguga because its protein content and yield are maintained very well during dry periods.

193. Comparison of the data obtained in this work with data from temperate areas of the world has revealed two important differences, one in the composition of crude fibre and the other in the composition of crude protein.

194. Crude fibre samples from these grasses were analysed for lignin, cellulose and nitrogen, and it was found that the recovery

of lignin in crude fibre, i.e. the lignin present in crude fibre as a percentage of that in the original material, decreased with the age of the plant and was generally much lower than has been reported for European grasses. This is important because it can be shown that this results in an *apparently* higher digestibility of crude fibre than in a grass in which the lignin is not so thoroughly extracted. French (Herb. Abs. 27, 1, 1958) has pointed out that the digestibility of crude fibre in the tropics is higher than in temperate areas. In fact, for feeds of crude fibre greater than 25 per cent, the average digestibility is about 52 per cent in temperate areas of the world and 65 per cent in tropical. It is unlikely that this difference in tropical regions is due to the animals being used in the trials, but the correct chemical interpretation is still uncertain. The lignin remaining in the crude fibre is about 2 to 3 per cent of the dry weight of the grass for these tropical grasses, compared with over 4 per cent for many temperate ones which have a lower content of crude fibre, whilst the methoxyl contents of the lignins in the grasses have the same range of variability, namely from zero to 8 per cent, the maximum which can be expected. It is not yet possible to assess the relative importance of true methoxyl-containing lignin and of the different carbohydrate fractions on the level of this crude fibre lignin, but it is clear that protein is not present in sufficient amounts in the crude fibre to be an important factor. This work is being continued, in particular by similar analyses of grasses from the U.K. for direct comparison with the local material.

195. A second possible difference may occur between the East African grasses and temperate ones in the crude protein fraction. Limited evidence suggests that this contains a smaller fraction of true protein than it does in cooler parts of the world. This work has not been followed up.

196. During the original analyses of the maturing grasses a large number of lignin values were obtained, and for each of these a crude protein correction was determined. The nitrogen associated with the lignins has withstood very severe chemical extraction and is probably largely unavailable to the animal digesting the grass. The remainder, or non-lignin nitrogen, has been found to bear a simple relationship to the total nitrogen, irrespective of the origin of the sample of feed. Further, the relationship is the same as that found by Glover, Duthie, and French of this Organization between the digestibility of crude protein and the total crude protein of ruminant feeds, except that the curve has

been displaced upwards, that is for a given total nitrogen content of a grass the proportion of non-lignin nitrogen to total nitrogen is about 15 per cent higher than the digestibility coefficient of the total nitrogen. The interpretation of this, like that of the Glover-Duthie-French digestibility curve, is still uncertain.

THE APPARENT DIGESTIBILITY OF CRUDE PROTEIN BY THE RUMINANT AND NON-RUMINANT

J. Glover and D. W. Duthie

197. In the last Annual Report we gave the results of a statistical examination we made on the relation between the crude protein content of a feed and its apparent digestibility by ruminants, using the results of all the digestibility trials made anywhere in the world which we could find. We found the digestibility coefficient (d.c.) of this crude protein was related to the crude protein content (c.p.) of the feed by the equation d.c. = 70 log (c.p.) − 15.

198. The digestibility coefficient of the crude protein was little affected by the crude fibre of the feed, but a more detailed examination of the data using exceptional feeds, particularly those in which the relationship between crude fibre and crude protein is abnormal, showed that the effect of crude fibre (c.f.) on the digestibility coefficient of the crude protein could be represented by the equation d.c. = 60 log (c.p.) − 0.33 (c.f.) + 5. We found that for normal feeds there was a fairly close relation between the crude fibre and the crude protein given by c.f. = 37 − 0.55 (c.p.) and that the original simple equation largely weighted for such feeds represented a curve traversing the set of curves represented by the new equation within the range of 0–50 per cent crude fibre.

199. In an attempt to estimate the digestibility of the non-protein part of animal feeds the relation between the nutritive ratio of the feed and its crude protein content was examined, where the nutritive ratio is defined as—

$$\frac{\text{Total digestible nutrients} - \text{digestible protein}}{\text{digestible protein}}$$

and is of particular interest because it is seen to link the non-protein component with the digestible protein fraction. Since the digestible

protein in the ruminant feed is a function of the crude protein content, there should be a relationship between the nutritive ratio and the crude protein content of the feed. This proved to be correct. It was found to be true for non-ruminant as well as for ruminant feeds, and it led to the further suggestion that there should be a relationship between crude protein and its digestibility coefficient in the non-ruminant. This has now been confirmed for pigs, horses, rabbits and man, and equations of the same general form as those for ruminants can provide an estimate of the digestible protein available in their feeding stuffs. However, the fibre component in the relevant equations is much more important than in the case of ruminants, and the equations indicate that the pig is very much more sensitive to crude fibre in its diet than either the rabbit or the horse: and that the rabbit and horse apparently digest the fibre to much the same extent; and these in turn are more sensitive to crude fibre than are ruminants. These equations, therefore, confirm the results experienced in practical feeding.

200. These relationships deal with the *apparent* digestibility of the protein, where the digestibility is defined as the proportion of the nitrogen consumed in the feed by the animal which is not excreted in the faeces. But faecal nitrogen consists of two fractions, the metabolic faecal nitrogen and undigested protein. Under the microscope sheep faeces, for example, consist of fibrous material held together by a dark-coloured gummy substance. The fibrous material appears to be unchanged plant particles, whilst the dark colloidal cementing substance presumably consists of metabolic faecal compounds. A method for separating these two fractions quantitatively is being sought in order to obtain a fuller understanding of the true digestion of the protein in the digested food by ruminants and by non-ruminants.

CARBOHYDRATE, NITROGEN AND PHOSPHORUS RELATIONSHIPS IN GRASSES

J. Glover

201. This work is being done in conjunction with Dr. H. W. Dougall of the Grassland Research Station in Kitale. The apparent loss of nitrogen as grasses age and become standing hays in the dry season affects stock farming because the crude protein of such material sometimes falls below maintenance levels. The carbohydrate, nitrogen, and phosphorus contents of a series of

six grasses has been measured weekly over most of a year and one of the first results from the experiment indicates that there is little, if any, real loss of nitrogen. As the plant grows it appears to take in nitrogen until it has headed, thereafter nitrogen intake ceases or is greatly reduced. Carbohydrate production continues and the carbohydrate/nitrogen ratio changes rapidly. As the carbohydrate content increases the percentage of nitrogen in the plant falls, although there is little if any real loss of nitrogen. As the digestibility of crude protein by the ruminant depends on its percentage level in the feed and not on its total amount, the situation may arise where the animal may lose condition in the presence of potentially adequate total amounts of nitrogen, which may be quite inadequate from the percentage standpoint.

ANIMAL BEHAVIOUR AND ANIMAL PHYSIOLOGY INVESTIGATIONS

J. Quarterman

202. A study of the comparative behaviour in physiology of Zebu and Grade cattle was begun as part of the programme of the Joint Animal Industry Division. The work fell into two main sections, namely investigating (1) the grazing behaviour of the two types of cattle in different conditions of heat stress, i.e. at Muguga (6,800 ft.) and on the Coast; and (2) differences in the physiology of digestion. The behaviour studies have been written up for publication and are described by Mr. Lampkin in the Annual Report of E.A.V.R.O., whilst the digestive physiology work, with which the author was more concerned, is described here.

203. It has frequently been observed that Grade cattle drink nearly twice as much water as Zebus under nearly all climatic conditions. This excess water drunk by Grades is lost partly as more dilute urine, and partly as wetter faeces. We were interested to know where in the gut this difference in the wetness became apparent. We found that the dry matter and osmotic pressure of the contents of the caecum and of the whole of the large intestine was higher for Zebus than for Grades, and the difference in osmotic pressure is greater than the corresponding difference in dry matter. We have also shown that this difference in osmotic pressure is not due to soluble organic matter or carbonate ions, but to a difference in the concentration of soluble salts, the Zebu having a higher concentration in the contents of the whole of the lower portion of

the gut than the Grades. It has been suggested that although the Zebu have not a greater power of digesting low quality feeds than the Grade, yet it has a higher rumenal fermination rate, and in consequence food moves faster through its gut so that it can consume more food than the Grade. A higher salt content in the gut would suggest a higher rate of activity, and so is in accord with this suggestion.

THE CARRYING CAPACITY OF MUGUGA PASTURE

H. P. Ledger

204. Production records of the 49 head of Zebu steers from the Northern Frontier Province of Kenya, which were purchased from the African Livestock Marketing Organization in July, 1956, continue to provide valuable information, both as to the productive capacity of the stock and of the pasture on which they are grazed. For the last 12 months these animals have been continuously grazed on 70 acres of naturally regenerated pasture (one-third Star grass, and two-thirds Couch *Digitaria abyssinica*). The main object of this trial is to obtain an estimate of the stock-carrying capacity of a typical pasture on this farm to help in formulating future experimental programmes. This trial has been of considerable interest outside the immediate requirement of the trial itself, because it is giving us an estimate of the rate of growth of unselected steers under our conditions, and it will also provide steers of known growth rate for carcass analysis.

205. The aim at the beginning of this trial was to provide sufficient grazing for the animals to maintain their liveweight during the dry season. We initially estimated the carrying capacity of our pastures to be about 2 to $2\frac{1}{2}$ acres per beast, and it was believed that at a grazing rate of $1\frac{1}{2}$ acres per beast a near-maintenance level of nutrition would be attained. However, the animals have put on liveweight at an overall rate of $\frac{3}{4}$ lb. per head per day for the first 420 days of the trial, and these production figures, based on the mean of three consecutive daily weights taken at 12 weekly intervals, are summarized in Tables 1 to 3. Table 2 shows that the rate of liveweight gain has been surprisingly constant throughout the 12 months of the trial in spite of a very long dry spell at the beginning. This trial is to be continued for a further 12 months.

TABLE 1

MEAN LIVEWEIGHT OF ZEBU STEERS IN LB. RECORDED AT 12 WEEKLY INTERVALS ON A MUGUGA PASTURE

No. Head	2 Teeth	4 Teeth	6 Teeth	8 Teeth	Date
	6	26	15	2	
Initial wt.	473	470	520	512	2–8–56
12 weeks	561	570	610	591	24–10–56
24 weeks	630	612	680	634	16–1–57
36 weeks	697	666	733	677	10–4–57
48 weeks	755	711	777	722	3–7–57
60 weeks	835	782	845	777	25–9–57

TABLE 2

MEAN DAILY LIVEWEIGHT GAIN PER HEAD OF THE ZEBU STEERS IN LB. RECORDED FOR 12 WEEKLY PERIODS

	2 Teeth	4 Teeth	6 Teeth	8 Teeth	Date
12 weeks	1·05	1·19	1·07	0·94	24–10–56
24 weeks	0·82	0·53	0·83	0·51	16–1–57
36 weeks	0·80	0·64	0·63	0·51	10–4–57
48 weeks	0·69	0·54	0·52	0·54	3–7–57
60 weeks	0·95	0·84	0·81	0·63	25–9–57
Mean overall gain in lb./day	0·86	0·74	0·77	0·63	

TABLE 3

DISTRIBUTION OF INDIVIDUAL LIVEWEIGHT GAINS PER HEAD PER DAY OVER PERIOD OF TRIAL

Age Group	Liveweight gain in lb./hd./day corrected to 1 decimal place							Total Head
	1·0	0·9	0·8	0·7	0·6	0·5	0·4	
2 Teeth	2	—	4	—	—	—	—	6
4 Teeth	—	4	8	9	3	1	1	26
6 Teeth	—	4	5	4	2	—	—	15
8 Teeth	—	—	—	1	1	—	—	2
No. Head	2	8	17	14	6	1	1	49
% of Mob	4	16	35	29	12	2	2	—

CARCASS EVALUATION

H. P. Ledger

206. The completion of the cold store has provided excellent facilities for a detailed carcass analysis. The object of these carcass analyses is to put on record such details of the conformation, history, and management of the live animal, together with those of its component parts when dead, as will enable a lucid study of its value as a meat producer to be made.

207. During the year a standard procedure for beef carcass analysis has been worked out, and analyses have already been made of a series of carcasses intended to provide information on the conformation at different stages of growth of the unimproved Zebu steer grown on grass only. Records are being kept under three headings—

(*a*) live animal records, which include its history, growth rate, and linear measurements;

(*b*) offal records, which give the weights of the parts of the dead animal which are not included with the dressed carcass, e.g. hide, blood, head, stomach, intestines and their contents;

(*c*) dressed carcass records, in which a dressed carcass weight is recorded. It is then divided into fore- and hindquarters between the 10th and 11th ribs, and these are then subdivided. The hindquarter is divided into hind leg plus top piece, and loin plus the flank, the forequarter into foreleg, and thorax plus neck. These four joints are weighed and then dissected. The weights of lean meat, subcutaneous fat, intramuscular fat, bone, cartilage and coarse connective tissue are then recorded. Bone weight is recorded in two ways. First, under the general heading of inedible material or butcher's bone, which is bone from which the edible meat has been removed but which retains the periostium and cartilage, and to which has been added the coarse connective tissue. True bone is also determined, which is that of bone free from cartilage, periostium and coarse connective tissue. In addition to the weights, linear measurements of the dressed carcass are recorded which include length, depth, circumference of round, etc.

208. As an example of the kind of results being obtained, the analyses of two fat mature and barren Zebu cows are given.

These animals, Brand Nos. 192 and 178, were representative of the extremes in conformation to be found in the N.F.D. Zebu. The former was a short-legged, fine-boned, compact animal, and the latter a long-legged, heavy-boned, coarse-skinned rangy animal. Table 4 gives a summary of the more important characteristics of the two carcasses. It is interesting to note that the short compact animal weighed 134 lb. less than the tall rangy one, yet it only carried 35 lb. less edible meat, and nearly all this difference came between the live weight and the dead cold weight.

209. In this particular example there is a considerable storage loss between the 24-hour dead cold weight and the dead cold weight at dissection. This is probably due to evaporation of water from the heavy layer of subcutaneous fat both animals had, and it was as large as it was because these carcasses were subject to excessive handling and delay before dissection took place, as they were used to establish a method of analysis. A more detailed example of the kind of information being obtained is given in a paper submitted to the *East African Agricultural Journal.*

TABLE 4

EXAMPLE OF CARCASS ANALYSIS

(*a*) *Killing Summary*

Cow No.	178	192
Type	Tall Rangy	Short Compact
Live wt. lb.	904	770
D.C.W. at 24 hrs. lb.	496	442
Killing Out % 24 hrs.	54·9	57·4
Carcass Grade	F.A.Q.	F.A.Q.

(*b*) *Analysis of Dressed Carcasses*

Cow No.	178		192	
	Weight in lb.	%	Weight in lb.	%
Loss between 24 hr. D.C.W. and Dissection	26·30	5·30	19·38	4·40
Edible Meat	411·54	82·97	376·08	85·09
Inedible Products less true bone	10·40	2·10	11·32	2·56
True bone	44·94	9·06	33·30	7·52
Dissection Loss	2·82	0·57	1·92	0·43
TOTALS	496·00	100·00	444·00	100·00

EXPERIMENTS ON THE FEEDING OF BACON PIGS

H. P. Ledger

210. During the year the new Danish-type feeding house which is equipped for the individual feeding of 168 pigs was completed, and it has for some months been working satisfactorily. Some weaknesses in the design have now become apparent and these are being overcome. It was for example found that the range of temperature between night and day was so large that it was affecting the performance of the pigs. To reduce this a lower ceiling was put in, together with baffles throughout the length of the building, and this has satisfactorily reduced the daily fluctuation in temperatures. Another problem which required investigation was that when the weaners were first put in to the feeding house they made very poor liveweight gains for the first three weeks, and it was found that this was due to them being subject to too great a change at this critical stage of growth. They are now brought in with their dams a fortnight before they are due to be weaned, and during this time the young pigs are offered food in a creep feed to accustom them to their new surroundings and feeding conditions whilst still suckling. It is of interest to note that both wet and dry creep feeds were on offer and all litters took the wet meal readily, whilst the dry meal was barely touched. Only three litters have so far been weaned on this new system, but the results so far obtained are most encouraging. Not only have liveweight gains been continuous since weaning, but conversion rates have also improved. Under the initial system of conversion the conversion ratios to bacon weight were of the order of 3.6 lb. of food per lb. of liveweight gain, and for the three litters it has varied from 2.7 to 3.2 lb.

211. An alternative method has been tried for housing sows with litters. The normal procedure had been to house them in cottage-type pig sties. The new method being tried is to put the sows in movable pig arcs on grass ten days before farrowing. The arcs are moved at least once a week, but more often if conditions demand it.

212. Work during the year has been hampered by a bacillary necrosis infection arising among the young pigs. It has now been controlled by sulphanilamide injections, but it has resulted in a severe setback in growth rates of infected pigs.

213. It has also been decided to try and improve the conformation of the herd, and for this purpose a pedigree Large White boar and an in-pig gilt were imported from the United Kingdom in August. The boar was shown at the Royal Agricultural Show at Nairobi and was awarded second prize in its class. The gilt was too heavy in-pig to show, but has since farrowed 13 pigs and reared 12.

214. *Cassava Feeding Trials.* Two trials in which cassava was used to replace barley in a baconer ration were carried out during the year. The first pilot trial indicated that cassava was a perfectly satisfactory component of a baconer ration provided the protein supplement was increased to compensate for the low protein content of the cassava. A working figure of nine parts of ground cassava and one part of meat meal for every 10 lb. of barley meal replaced was used. The second trial in which increased proportions of cassava were used, corroborated the finding of the first trial. In this second trial four rations were under test and 16 pigs were allotted to each ration. Each group of 16 pigs was divided into two groups of eight, one group being used for testing rations under *ad-lib* feeding, and the other under controlled feeding where a limit of 6 lb. of food per day was imposed. It was found that the conversion ratios were the same for the *ad-lib* and the controlled feeding, and it was also the same for the four rations of which the highest cassava ration contained 46 per cent of cassava in the ration for pigs up to 90 lb. in weight, and 35 per cent thereafter.

EXPERIMENTAL FARM

A. F. Dent

215. This report covers an 18-month period instead of the usual 12, and during this period a reorganization of the Joint Animal Industry Division has taken place, resulting in part of the African labour force going over to E.A.V.R.O. With the easing of the Emergency it has been possible to have a more permanent African staff of Assistant Recorders, Tractor Drivers and Stockmen. The number of casual employees has fluctuated according to work commitments.

216. For the first six months of this period the rainfall, although average, was so badly distributed that 12½ acres of Star (*Cynodon dactylon*) and Kikuyu (*Pennisetum clandestinum*) grass

planted during the long rains of 1956 had to be ploughed in. This was planted to oats, and then during the January rains replanted to Star.

217. All the fencing on the farm has been realigned to enable controlled grazing to be undertaken by means of electric fences. As a result of the reorganization of the Division all fencing is now the responsibility of E.A.V.R.O. By the end of May, 1957, all the paddocks on the west side of the farm had been supplied with drinking troughs and piped water.

218. During the period under review the area on the east side of the farm (including the 80 acres handed over by the Forestry Division of E.A.A.F.R.O.) has been cleared. The majority of this area has had permanent pastures established due to the very favourable long and short rains during 1957, and there have been no failures. Fencing on this side of the farm still remains to be put in hand, but five water troughs have been installed.

219. A certain amount of Kei-apple fence has been planted with a view to replacing the wire fencing, particularly around the farm buildings. The roads round the farmyard have all been metalled and murramed, and the road as far as the cattle dip will have been completed by the end of the year.

220. The main development on the farm has now been completed with the exception of four projects: —

(*a*) Fencing on the east side, which is now the responsibility of E.A.V.R.O.

(*b*) Building permanent African staff houses in the farm village to replace the present mud and wattle buildings.

(*c*) The erection on a rodent-proof food store, so that foodstuffs can be bought in bulk when they are cheapest. This would also release numerous odd buildings for their proper use, such as boxes for sick animals.

(*d*) Building more pigsties for the breeding stock which are at present housed in very temporary quarters. In view of the bacillary necrosis (*Fusiformis necrophorus*) infection recently encountered, it has been found advisable not to let any sow farrow in these wooden temporary quarters, but to rely entirely on the six old sties with concrete runs until more are available.

221. *Cattle and Pigs.* These are used entirely for experimental purposes, and Mr. Ledger's reports on the results are given in the preceding sections of this Report.

222. *Sheep.* A small flock of Dorset Horn-Masai cross is being maintained.

223. *Poultry.* This section has now been closed down.

224. *Oats.* These have been grown on an extensive scale in both long and short rains, and all areas, with the exception of one, have had superphosphates applied. These have been underplanted with Star grass which has come away well. In certain other areas Lucerne was included when the oats were sown in an attempt to improve the grazing of the final pasture. The oats are used either for hay, or as a green food, or are grazed.

225. *Edible Cannas.* These were replanted in the short rains of 1956 in order that they might multiply and be available should they be required for feeding experiments.

226. *Kale.* A further area was planted up during the long rains to replace the area planted in 1956.

227. *Potatoes.* Owing to the very prolonged growing period 1955–1956, due to the fact that the short rains were so intermittent, only a very poor crop was harvested and a severe attack of eelworm noticed. No potatoes were planted during the long rains on the farm, with the exception of Dr. Pereira's arable experimental area —these yielded fairly satisfactorily. A small area has been planted up during the 1957 short rains for seed purposes.

228. *Sweet Potatoes.* These were originally grown on a small scale during the short rains of 1956 and yielded well during the long rains of 1957. They were replanted and multiplied in order that sows may be turned on them during the dry weather.

229. *Beans* were planted on Dr. Pereira's experimental area during both short rains periods of 1956 and 1957.

230. *Field Experiments.* There are one major field experiment and two minor on the farm. The major is an experiment on the direct and residual effect of two levels of phosphate fertilizer on a Star grass pasture, and is run in conjunction with Dr. Dougall of the Grassland Research Station, Kitale. It was started in the long rains of 1956 and will continue for several years. The two

minor experiments are designed to find out the cause of the very low productivity of an appreciable area at the far west end of the farm, so that these areas can be ploughed out and brought into more productive pasture as soon as possible.

FORESTRY

SILVICULTURE RESEARCH

A. L. Griffith and P. Howland

231. Work has in general continued on the long-term lines laid down for us by the E.A. Advisory Council in 1952. The main emphasis has, as last year, been on the Information Section, softwood problems and the development of Muguga estate for experimental purposes.

232. There was no change in the staff during the period.

233. The Silviculture Specialist Committee held its fourth meeting in January, 1957. This meeting finally delimited the Quality Classes of the cypresses of the *C. lusitanica* group in East Africa, and decided on the method of collection of the necessary data for the production of yield tables. The application of the work done on date of planting and soil moisture at planting time to practical work and extended experiment in the Territories was discussed.

234. The fourth Forestry Course was held in November, 1956, and was attended by 12 officers including an A.C.F. from British Somaliland. The fifth course was held in November, 1957. 17 delegates attended, and thus 81 forest officers and foresters have now been to the course. One agricultural officer from Uganda also attended the fifth course. The second half of both these courses was held at Molo in the Londiani Division of Kenya, to study softwood tending. We are grateful to the Chief Conservator of Forests, Kenya, for this facility.

235. We had visits of a week's duration by the Tanganyika Forest Rangers Classes. The Forest School from Olmotonyi came in July, 1956, and the Forest Ranger Class of the Tengeru Natural Resources School in September, 1956. Both schools paid similar visits in the second half of 1957. The Kenya Forest Ranger School from Londiani visited us in September, 1957.

236. The Silviculturist is now a member of the E.A. Timber Advisory Board, and attended a meeting in Moshi in March, 1957.

237. In July, 1956, the Silviculturist visited the Centre Technique Forestier Tropical at Nogent-sur-Marne near Paris to

discuss tropical forest research with his French opposite numbers, and went on to the 12th Congress of the International Union of Forest Research Organizations at Oxford. This was followed by a study tour of the north of Scotland to see the work done in the introduction of exotic conifers.

238. The Silviculturist attended the 7th British Commonwealth Forestry Conference in Australia and New Zealand in August and September, 1957. This conference was preceded by study tours of the dry *Eucalyptus-Callitris* forests of inland New South Wales, and of the forests of Northern Queensland, Papua, New Guinea, and New Britain, and was followed by a study tour of exotic forest problems in North Auckland, New Zealand. On the return journey the Silviculturist saw something of the teak and pine forests of Indonesia. The value of this conference and its study tours to East Africa will be realized when it is remembered that at least 90 per cent of the trees grown in East Africa are Australasian in origin.

239. A feature of the work of the period has been the stocktaking and writing-up of the experimental work done at Muguga since 1952 on the general problems of the establishment of plantations of exotic softwoods in an area with an unreliable climate.

240. The headings of the report that follows are those of the long-range programme.

I. INFORMATION SERVICES

241. The Forest Bureau was maintained and expanded, and now contains 1,925 Specific Ledger Files and 880 General Ledger Files. The new service of issuing, periodically, lists of highlights of information ledgered, has been continued, and has proved very popular. Many enquiries were received and answered, and we have been happy to welcome many visitors, official and unofficial, from all walks of life and business who came to see for themselves the various species of trees and hedges actually growing.

II. STANDARDIZATION OF RESEARCH PROCEDURE

242. Several modifications of our forest research procedure were decided on by the Silviculture Specialist Committee.

III. RESEARCH ON SOFTWOODS

243. In the following report on seed and nursery problems Mr. W. B. May (Horticulture) and Mr. P. Dickinson (Plant Quarantine) have both collaborated.

A. Seed Problems

244. (*a*) *Cupressus lusitanica* progeny trials. The replicated experiments are now three years old and so far show no appreciable differences in height growth or vigour from stock of (1) five different sizes of seed, and (2) three different cotyledon numbers (2, 3 and 4) from each parent tree. Within each treatment there are, however, considerable differences in colour and form and these are being watched.

(*b*) *Seed Orchards.* Considerable progress has been made in the technique of grafting under field conditions (Mr. May) and under glasshouse quarantine conditions (Mr. Dickinson). During the year a trial sample of grafting material of elite *Pinus radiata* was obtained from Australia, because before serious seed orchard work can start we have to perfect the technique for the successful transport of material over very long distances and through a number of changes of climate. This trial sample arrived in good condition and a high percentage of the grafts were successful. The second consignment is held up by the Australian quarantine authorities, as it is suspected of a rust and a fungus neither of which is at present known in East Africa.

B. Nursery Problems

245. Experimental work in the nursery at Muguga has continued. This is long-term work for many repetitions are required to cover the climatic range. Weather variations have been very great, and in the past five years 1952 was nearly normal, 1951 and 1954 were above average and 1953 and 1955 were well below average for rainfall. 1956 with 27.9 in. was below the normal of 36.4 in., but like 1955 the rain was well distributed and the planting "take" and subsequent growth were good. 1957 so far is above average, and the long rains although late were regular and plentiful.

246. *Comparison of Different Pine Soils.* Previous work has shown that under Muguga conditions the addition of pine soil is not necessary in the nursery, and that a good balanced soil

mixture (Muguga Standard Mixture which contains a basic quantity of N.P.K.) has produced better plants than boxes with a pine soil inoculation. As the result of this an experiment was started in 1954 to compare the results obtained with pine soils from under the oldest pine plantations of different species from different places. The soil used was that of the first three inches below the undecomposed litter from *P. patula* and *P. radiata* stands at Kinale and Kitiro. In the 1956 experiments survival percentages were high and varied from 94 per cent to 100 per cent. The experiment needs further repetition, but the three years' results so far indicate that the two species used (*P. patula* and *P. radiata*) do not show preference for their own soils (i.e. for possibly specific mycorrhyzae), at all events under Muguga conditions, but that the four soils used are merely of different qualities. In the six experiments over three years with both species, the soils have sorted themselves out in the same order each time.

247. *Fertilizers.* The experiments described in previous reports were repeated with *P. patula* seedlings. N.P. and K. were applied in all combinations and at two rates which were:—

Fertilizer rate 5.	N.	Sulphate of ammonia 540 lb. per acre or 8 gm. per box (Soluble N. found on analysis to be 20 per cent).
	P.	Double superphosphate of lime 540 lb. per acre or 8 gm. per box (Soluble P_2O_5 on analysis found to be 39 per cent).
	K.	Sulphate of potash. 270 lb. per acre or 4 gm. per box (Soluble K_2O found on analysis to be 52 per cent).
Fertilizer rate 10.		Twice the above quantities.

The experiments confirmed the general indications previously obtained, i.e.:—

(*a*) The response to fertilizers varies with the annual rainfall being greater (about 30 to 33 per cent) in a normal to wet year than in a dry year (about 10 to 15 per cent).

(*b*) There is very little difference in response between the "5" and "10" rates of application, and hence the latter rate is unnecessarily high.

(*c*) The effect of application of fertilizers 12 weeks after pricking out is very small compared with application six weeks after pricking out.

(*d*) The pine seedlings gave the largest response to the nitrogen fertilizers, and the smallest to the potash, but the best plants were those given nitrogen, phosphate and potash.

(*e*) All the experiments made in the last six years have shown that the application of a basic quantity of N.P.K. is a well worthwhile insurance. The quantity used is small, 3 oz. per square yard of bed or half an ounce per box, but it ensures that the basic nutrients are present.

248. The above experiment was replicated interterritorially and the results that have so far come in (from Uganda) generally confirm the above indications. They, however, do indicate that in some cases considerable work is still needed to improve the soil structure and soil texture of the nursery to raise the nursery stock to a reasonable standard. Fertilizer alone is not sufficient, nor indeed is it the first consideration.

249. *Minimum Fertilizer Requirements.* The experiments described above show that the two levels of fertilizer application have in general produced the same response. Experiments were therefore started to measure the response of seedlings to lower rates of fertilizers. Two years' experiments with the two pine species have so far failed to show any appreciable response to a fertilizer application of less than rate "5" described above. The experiments continue.

250. *Organic and Inorganic Fertilizers.* The experiments to test whether tree seedlings respond bettter to organic fertilizers, whose nutrients are likely to become available over a period of time, than to inorganic fertilizers were continued. The organic fertilizers used were dried blood and hoof and horn as nitrogen sources, and bone meal as a phosphate source (though this probably contained a certain amount of nitrogen as well). The levels of application were approximately the same as in the preceding experiments, and the plants were seedlings of *P. radiata* and *P. patula*. The results of the first two years of experiment are that the inorganics give apparently the same growth response as the inorganics at the end of the first year.

251. *Transplant Spacing in Beds.* The experiment was continued in which the plants were pricked out at two by two, three by three, and four by four inches. Wider spacing was not used as the experiment had to keep within practical district economics. In the two years of experiment there was in general little difference in height growth or survival percentage between the treatments, but the wider the spacing the sturdier and better developed the plant. It remains to be seen how they behave when planted out.

252. *Effect of Restricting Evaporation—Transplant Boxes.* Experiments in this subject were continued. Treatments were (*a*) boxes sunk to ground level, (*b*) boxes placed normally on a gravel base, and (*c*) boxes placed normally on a gravel base, but mulched with chopped straw after the short rains, i.e. for the dry season of January, February and March. The species used were *P. patula* and *P. radiata*. The results of the first two years' work are that the sunk boxes and the mulch increased the height of *P. radiata* by 7 per cent and 2 per cent, and of *P. patula* by 20 per cent and 17 per cent respectively, again demonstrating that *P. patula* is much more sensitive that *P. radiata*. It should be noted that sinking the boxes is much more expensive, as (*a*) they have to be dug up frequently for pruning off the roots which have grown through the bottom of the boxes, and (*b*) wear and tear and termite damage to the boxes is severe.

253. Although much more repetition is required it appears unnecessary to sink the boxes if one is prepared to water adequately. It is definitely worth while, however, to mulch boxes of *P. patula* during the dry hot weather.

C. Short-term Planting-out Problems

254. These short-term experiments were started in 1952 to compare different establishment techniques. So far 75 experiments have been completed, and 11 have been started in the long rains of 1957. The results as summarized are only tentative, as the experiments must be repeated for a number of years in order to cover the climatic range.

255. The most important feature in the period under review is the appraisal and write-up of the last five years' work on some aspects of planting in our unreliable climate. The summary of this work, as presented to the 7th British Commonwealth Forestry Conference is:—

(*a*) The unreliability of the climate both annual and seasonal has been determined.

(*b*) Only the very best nursery stock should be used, and the quality of this stock can be raised by improving the texture and composition of the local soil by the addition of local ingredients. It is necessary to add a small quantity of N.P.K. to ensure that the basic nutrient elements are present. Early pricking out of seedlings within one or two weeks of germination is essential.

(*c*) The nursery stock should be planted out as early in the planting season as is reasonably safe. This "earliest safe date" can be determined by keeping a daily record of the rainfall build-up after an arbitrary date (as distinct from the total rainfall and allowing for the probable daily evaporation), together with a periodic estimation of the depth of soil wetting.

(*d*) The plants can with advantage be planted in the field deeper than they were grown in the nursery. This deep planting can be as much as burying up to one-third to one-half of the stem without deleterious effects, thus initially putting the roots of the seedlings in the deeper layers of the soil, which dry out more slowly in case of an early break in the rains or an early cessation of the rains.

(*e*) Even bare-rooted stock can be stored in wet gunny for as long as 48 hours after lifting in the nursery if necessary without deterioration. This should be avoided if possible.

(*f*) Exposure of the plants between the time of lifting in the nursery and planting in the field even for as short a period as 15 to 30 minutes can be fatal, and such exposure should be avoided at all costs.

(*g*) Early weeding in the first two years has a very marked effect on the crop. The retarding effect on height growth by deep-rooted grasses may be of the order of 150 per cent after two years. It is essential that efficient early weeding is carried out, as it gives the forest crop its best chance against the weeds and thus considerably reduces early maintenance costs.

256. *Planting Stock from Different Dates of Sowing in the Nursery.* With *P. patula* the sizes of plants put out have ranged

from 2 to 15 inches. Measured after a year the increment and vigour of the larger plants has been the best, and except with the smaller plants (six inches and under) survival percentage has been good. With *P. radiata* plants put out have varied in size from 3 to 25 inches. Survival percentage for all sizes has been very good. Again, within the range used, the bigger the plant the greater the increment and vigour. This species is very hardy and it appears unnecessary to use plants larger than those that can be raised in the nursery in one year with our present techniques.

257. The sizes of *C. lusitanica* used have varied from 3 to 30 inches. Survival percentage has been very good indeed except for the smaller sizes. Again, the bigger the plant the better the increment and vigour. With this species it appears that post-long-rains sowings will produce plants sturdy enough for the purpose.

258. *Different Dates of Planting.* We have now four years' experimental experience of weekly planting from the middle of March to the end of May each year for *P. patula, P. radiata,* and *C. lusitanica.* With all three species, height growth and survival percentage drop markedly with late planting. In these experiments at each date of planting, an estimate of soil wetting is made, and from the rainfall records the rainfall "build-up" is calculated allowing for the daily evaporation.

259. The indications of these experiments are that the criteria for the earliest safe date for planting at Muguga are: —

(*a*) Planting should not be started before 15th March.

(*b*) The critical rainfall build-up is about $\frac{1}{2}$ to $1\frac{1}{2}$ inches.

(*c*) The critical depth of soil wetting is about 2 to 3 inches for *P. patula,* and $1\frac{1}{2}$ to 2 inches for *P. radiata* and *C. lusitanica.* All these three criteria *must* be fulfilled at the same time for "safe" planting.

260. It is not suggested that these conditions apply to areas other than Muguga. They are given as a demonstration of a method of estimating the possibilities of success in planting in areas which are climatically difficult.

261. *Comparison of Different Depths of Planting.* Six experiments with *P. patula, P. radiata* and *P. leiophylla* have been done in the last three years in which plants were planted (*a*) at the collar, (*b*) two inches above the collar, and (*c*) four inches above

the collar. In no case has the deep planting caused any deleterious effect, but has caused a stimulation of height growth of from 10 to 30 per cent. Similar results have been obtained in N. Carolina of the U.S.A. with *P. taeda, P. rigida, P. virginiana* and *P. echinata.* This practice of deep planting may prove even more beneficial under more unreliable climatic conditions than those of Muguga, for it tends to put the root systems of the young seedlings into the deeper layers of the soil.

262. *Comparison of Bare-rooted and Ball-planted Transplants.* Six experiments have been done over the past three years with *P. patula* and *P. radiata.* Results have been very variable, and indications so far are that, in Muguga conditions, it is well worth while to take the extra trouble (and small extra expense) and used ball-planted transplants. The small gain in cost is not worth the risk of using bare-rooted plants, except under the most favourable conditions.

263. *Comparison of "Normal" and "Overgrown" Nursery Stock.* These experiments were continued with *P. patula* and *P. radiata.* The plants used were from beds and boxes both one and two years old. Indications so far are that it is not economically worth while to grow the much more expensive older and larger plants. The experiments, however, need much more repetition.

264. *Effect of Storage of Naked Rooted Stock.* Stock of both *P. patula* and *P. radiata* was lifted, and all soil shaken off the roots. It was then bundled in wet gunny, taken to the planting site, and one set planted immediately. The second and third sets were thoroughly wetted and left for 24 to 48 hours respectively. The indications of three years' work are that *P. patula* is more sensitive than *P. radiata,* but that both species *can* be stored thus for 48 hours if necessary without serious deterioration. The practice is to be deprecated, and planting should be done as soon after lifting as possible.

265. *Effect of Exposure of Naked Rooted Stock.* Parallel to the above experiment naked rooted stock of *P. patula* and *P. radiata* were (*a*) planted at once, (*b*) exposed for 15 minutes, (*c*) exposed for 30 minutes, (*d*) to (*f*) exposed for 1 hour, 3 hours, and 6 hours. With both species an exposure of even as short a period as 15 to 30 minutes was fatal. This demonstrates the need for careful supervision of the storage of plants between lifting in the nursery and planting in the field.

266. *Planting Stock Raised by Different Box and Bed Techniques.* The experiments with *P. patula* were continued, and the results of three years of experiment show that, under Muguga conditions, it is not worth while to use the cheaper bed method. The use of boxes is more expensive, but it is a worthwhile insurance against failure in adverse weather conditions.

267. *Cover Crops in Young Cypress Plantations.* Modern methods of pruning and thinning cypress and pines tends to keep the plantations open in the early stages and vulnerable to invasion by grass. An experiment was started in 1954 to try and introduce a cover crop into one year cypress plantations that would keep grass out. The cover crops tried were *Prunus salasii, Tephrosia vogelii, Centrosema pubescens,* and *Pueraria javanica.* At three years old the best crop is the *Tephrosia* up to 6 feet high, and next is the *Prunis* which is 2 to 3 feet high and likely to be better in the future. The *Centrosema* and the *Pueraria* are complete failures.

268. *Effect of Shamba Crops and Cultivation.* An experiment was started in 1955 in conjunction with the soil physics division to study the effects of *shamba* crops and cultivation on the height growth and survival percentage of the forest crop. The first year's work was ruined by the ravages of buck and porcupine on the *P. patula.* The plot was fenced against the pests and replanted with *P. radiata.* It was soon realized that different depths of cultivation were impossible to control, and so the experiment has developed into the effects of different *shamba* crops on the forest crop. The *shamba* crops were (*a*) maize, (*b*) beans, (*c*) maize and beans together, and the general result at the end of the first year is that the *shamba* crops have reduced the growth of the forest crop by about 10 per cent in height. The crops had no appreciable effect on survival percentage, which was in general high and from 96 to 98 per cent.

D. Long-term Problems

269. The experiment started in 1955 to determine the effect of the season of pruning on the rate of wound occlusion of *C. lusitanica* was continued. This is part of an interterritorially replicated experiment. So far no effect of season has been observed in the Muguga experiment, and after 32 months the dry season (1st February) wound area had occluded 99 per cent, that of the rains pruning (1st April) 98 per cent in 30 months, and the post-rains (1st June) pruning 100 per cent in 26 months. The August,

October and December prunings had occluded 93 per cent, 88 per cent and 80 per cent in 26, 24 and 22 months respectively. In general at present the lack of complete occlusion in any of the treatments is due to one or two "obstinate" wounds.

270. In the Uganda experiment started in February, 1956, at Mafuga near Kabale in the West of the territory, the first 20 months has shown no effect of season of pruning on the rate of occlusion. The prunings of February, April, June, September, October, and December, have shown occlusion of 99 per cent, 97 per cent, 87 per cent, 73 per cent, 66 per cent and in 20, 18, 16, 13, 12 and 10 months respectively. These figures roughly compare with 99 per cent, 98 per cent, 100 per cent, 93 per cent, 88 per cent and 80 per cent occlusion in 32, 30, 26, 24, and 22 months respectively, which occurred in similar treatments at Muguga. The general rate of occlusion at Mafuga has thus been a little faster than at Muguga.

271. Interim measurements of the experiments in Kenya and Tanganyika have not yet come in.

272. In the second experiment at Muguga to determine the rate and direction of occlusion, measurements were taken on four radii at right-angles on each wound. In the initial wounds the biological centre of the branch was seen not to be at the geometrical centre, but was displaced 7 per cent above and 5 per cent to the left of the latter. The rate of occlusion was slow and roughly the same in all four directions for the first nine months. Then the rate of occlusion greatly accelerated from the right and left and top of the wound, and slightly accelerated from the bottom of the wound. After 30 months the radii right and above the biological centre were totally occluded, and the radii left and below the biological centre occluded two months later. Thus the occlusion has been to the biological centre of the wound and not to the geometrical centre. This is a most important fact to have established, as the wood most susceptible to successful attack by *Oemida* and *Androeme* is the heart wood, or dead wood, and this is concentrated around the biological centre of a pruning wound.

E. Species Trials (Mainly Exotics)

273. Twenty-four new plots were planted in the arboretum of small trial plots. 1957 was the sixth year of planting. Each plot

consists of 7 by 7 trees at 8 by 8 feet spacing. These plots are tended, pruned and thinned as ordinary commercial plantations. In addition, for each species, three specimen trees are planted at a wide spacing and left untended except for weeding. The object is to demonstrate the difference for each species or strain between a plantation crop and the untended free grown tree.

The arboretum now includes:—

Eucalypts . . .	48 plots (43 species)
Pines . . .	30 plots (24 species)
Cypresses . . .	17 plots (15 species)
Callitris . . .	3 plots (10 species)
Acacia . . .	14 plots (10 species)
Others . . .	50 plots (50 species)

A total of 162 plots, 145 species.

274. An outstanding feature of the arboretum so far in its first five years has been the demonstration of pests. The cypress canker (*Monochaetia unicornis*) has continued its havoc in the *Cupressus macrocarpa* plot, and in the first five years 47 per cent of the very healthy young trees have been killed. In the adjacent *C. lusitanica* plot only one tree has died, i.e. 2 per cent. At present it seems likely that serious loss from this disease may occur in the near future in *C. pygmaea*—so far there has been 20 per cent death.

275. The *Eucalyptus* weevil (*Gonipterus scutellatus*) first appeared in September, 1955. So far 15 species have been attacked in varying degrees. The heaviest attacks have been on *E. maidenii, E. viminalis, E. globulus, E. tereticornis* and *E. bridgesiana.* Four species *E. triantha, E. camaldulensis, E. salmonophloia* and *E.* sp. (from Zanzibar and probably near *E. camaldulensis*) are among those attacked, and are not mentioned in the list of Tooke as susceptible to the weevil in South Africa.

276. Some species have shown remarkable growth. The height given is the "top height", i.e. the mean height of the best 100 trees per acre. The plots are approximately one-tenth of an acre in area and the top height measured in each plot is the mean height of the tallest ten trees. The diameter given is the mean d.b.h. of all trees in the plot.

Cupressus benthamii	31 ft. and 4.9 in. diameter in 6 years
Pinus radiata	24 ft. and 4.3 in. diameter in 6 years
Pinus patula	23 ft. and 3.8 in. diameter in 6 years
Pinus canariensis	28 ft. and 3.6 in. diameter in 6 years
Pinus taeda	21 ft. and 3.9 in. diameter in 5 years
Cupressus lindleyi	25 ft. and 4.3 in. diameter in 5 years
Callitris calcarata	14 ft. and 2.4 in. diameter in 4 years

Among the eucalypts the following are worthy of note.

Eucalyptus saligna (Australia)	49 ft. and 6.0 in. diameter in 5 years
E. saligna (Kenya)	51 ft. and 5.9 in. diameter in 6 years
E. botryoides	53 ft. and 5.9 in. diameter in 5 years
E. marcarthuri (a windbreak species)	40 ft. and 4.6 in. diameter in 5 years
E. grandis	42 ft. and 5.4 in. diameter in 4 years
E. regnans	55 ft. and 5.2 in. diameter in 4 years
E. fastigata	41 ft. and 5.2 in. diameter in 4 years
E. globulus	40 ft. and 4.2 in. diameter in 3 years
E. cloeziana (a heavy purpose timber)	35 ft. and 3.7 in. diameter in 3 years

277. *Live Hedges.* The five new species planted last year are all growing well, and *Caesalpinea sepiaria* (Mauritius thorn) has already had to be clipped several times in the first year to keep it within the 5 feet high 4 feet wide stipulated. Of the original nine species now three years old, all have grown to the stipulated size and have had to be clipped repeatedly, except *Aberia caffra* (Kei apple) which is nearly up to size and *Rosa multiflora* which was badly browsed by buck.

278. *International Eucalypt Trial.* During the year a series of plots were established of 12 species or strains of eucalypts. This experiment consists of five replications of each of the species. It is part of a project of the International Union of Forest Research Organizations, and is being repeated in some 16 different countries. The Muguga trial is, however, the only one nearly on the equator.

IV. ENUMERATION AND V. REGENERATION OF HARDWOODS

279. Further work was done in the territories. E.A.A.F.R.O.'s contribution was purely advisory.

VI. SHORT-TERM TREE CROPPING

280. The replicated ten-acre experiment to test the relative fuel yields of three eucalypts is now two years old. Height growth differences are still very significant, and the order at present is *E. grandis* of Australian origin, *E. saligna* of Australian origin, and the local *E. saligna* third.

281. A perusal of paragraph 276 shows that we have other gums growing as fast or faster than these, and a very much bigger experiment with a number of other gum species will have to be done if we are to find our best economic fuel and pole producer. Some of these other promising gums are: *E. regnans, E. fastigata, E. bridgesiana, E. botyoides, E. macarthuri, E. muelleriana* and *E. resinifera.* Such fast growing species as *E. globulus* are ruled out where the weevil exists.

VII. YIELD TABLES FOR IMPORTANT SPECIES

282. The quality classes for the cypresses of the *C. lusitanica* group in East Africa were delimited by the Silviculture Specialist Committee, and arrangements made for the collection of the data necessary for the compilation of yield tables. It is of interest how very closely the E.A. *C. lusitanica* quality classes compare with those of *Pinus radiata* for South Africa. The plot data have started to come in and are being computed.

VII. MUGUGA (E.A.A.F.R.O.) ESTATE

283. Maintenance of the estate continued. Work included gum and wattle thinning, the clear felling of old wattle for the new farm area and for conversion to softwoods for experimental purposes, and eucalypts to provide fuel and poles for the station. With the 1958 planting, the conversion of the estate from wattle to the experimental crops for agriculture and forestry research will be virtually complete.

FOREST ENTOMOLOGY

J. C. M. Gardner

284. The present Entomologist resigned at the end of his second tour and proceeded on leave in April. The survey of East African Forest Insects was continued actively, and much new information has been recorded. The reference collection of identified insects has been greatly augmented, and in consequence rapid diagnosis is correspondingly simplified. We continue to be indebted to the Commonwealth Institute of Entomology for assistance in identification of work; but there is a growing number of apparently new species in our collection in families for which no taxonomic specialists are available. An illustrated booklet *Insects Injurious to East African Timbers* was prepared for publication for the East African Timber Advisory Board, and *An Annotated List of East African Forest Insects* was prepared for publication.

HORTICULTURAL SECTION

W. B. May

Forestry Work

285. This is described in the silvicultural section of this Report. The Horticulturist is responsible for carrying out all the forest nursery experiments referred to. He is also responsible for raising some 120,000 plants, chiefly conifers and eucalypts, which are needed for estate planting. The material for the planting of 24 new arboretum plots was raised in the nursery.

286. *Methods of Grafting.* The technique for grafting imported *Pinus patula* cuttings on to locally-raised stock has progressed sufficiently far for it to be possible to accept from other countries living material from elite trees at the Plant Quarantine Station, and to be certain the great majority of the grafts will take. After these grafts have been through the Plant Quarantine Station they will be planted out for work on the establishment of seed orchards.

Agricultural Work

287. A crop of cotton was successfully raised in the nursery, artificial watering being resorted to when necessary. This crop took twice as long as it would have done in a normal cotton growing area to flower and to boll. It was grown for the biochemist.

288. An experiment in which lupins are grown continuously on the same piece of land is being carried out for the Spectrochemical Division. In addition, an experiment designed to study the breakdown and build-up of organic matter in the soil is being carried out for the Chemistry Division.

289. A few experiments have been carried out on the use of polythene sheeting for keeping live cuttings in good condition for vegetative propagation.

Tours

290. The Horticulturist toured extensively in the three Territories, holding 3-day courses of instruction on forest nursery techniques and the raising of plants generally. Some 15 of these courses were held, and approximately 450 agricultural and forestry staff attended them.

291. He also toured the Bukoba area of Tanganyika and advised on the layout of nurseries and the raising of coffee transplants, chiefly Robusta coffee, from seed.

MISCELLANEOUS SCIENTIFIC SERVICES

JOINT E.A.A.F.R.O./E.A.V.R.O. LIBRARY

L. D. Verdcourt

292. Mrs. S. Evans rejoined the staff towards the end of 1956 and continued working until the end of July, 1957. During that period it was possible to keep well up to date with the routine work of the library, and various long-term tasks of re-arranging, cataloguing reprints, etc., were begun. However, when the librarian is working alone with only one African assistant it is quite impossible to do more than the routine work and checking. This is because the library has become increasingly busy during the last two years. Requests for publications not in the library numbered 114 in 1957, and almost all were obtained from other libraries on loan. In 1955, 65 references were obtained, which shows a big increase in the use of the library, and naturally indicates how much more time is being spent on this type of work by the librarian. Many of these references were obtained on microfilm, and it is hoped to purchase a reader during the coming year as it is obvious that it would be well used and a valuable piece of library equipment.

293. The reprints collection had reached such enormous proportions that it was decided to reduce it drastically in size. This was done by checking the 5-year collection against the library stock, and where it was found that a reprint was duplicated in a bound volume it was set aside for six months for any interested reader to take away. At the end of that period the reprints which remained were given to other libraries in East Africa, mainly the Royal Technical College, which is trying to build up a reference collection. Duplicates of scientific periodicals were dealt with in much the same way, and after being offered to other libraries in East Africa they were eventually discarded. More gaps have been filled in the missing sets of periodicals through the British National Book Centre Exchange scheme. This scheme involves a good deal of work in indexing duplicates for disposal and circulating lists to other libraries: also in making lists of "wants" at Muguga and checking them against incoming lists. The result may be only one of two parts of a volume, but it is felt a worthwhile part of the librarian's duties, because publications which are received thus

are usually out of print and therefore unobtainable from other sources.

294. The librarian suggested to the Directors of E.A.A.F.R.O. and E.A.V.R.O. that there is a need for a central High Commission bookbinding service. After submission to the Research Council the idea has been developed, and the E.A.A.F.R.O./E.A.V.R.O. bookbindery can now undertake to bind about 60 volumes per month for other institutions who are not fortunate enough to have the necessary specialized equipment. This scheme has not yet come into full operation but should be well established by the middle of 1958.

295. In the E.A.A.F.R.O./E.A.V.R.O. bookbindery 1,793 books were bound between 1st July, 1956, and 16th December, 1957, and 572 pamphlet boxes were made. There were several staff changes during this period, and much credit is due to the head bookbinder for the increasing output and high standard of work.

296. The library work is continuing steadily and progress is being made, but it is hampered by a lack of money to buy text-books and reports. At present the library is not keeping pace with the growth of the two organizations, but it is hoped that this will be remedied in the next few years.

EAST AFRICAN AGRICULTURAL JOURNAL

D. W. Duthie

297. During the year under review there has been a marked increase in the number of papers received for publication, and in consequence printing costs have risen beyond the financial resources of the Journal. Increased financial aid has been sought from the three East African Governments, but even with this the cost of publication will have to be kept down by more drastic editing of the longer articles.

298. The four numbers published in 1957 contain articles on a wide range of subjects, including a series of papers recording the proceedings of the First East African Herbicide Conference. A lengthy paper on the taxonomy of new East African Prioninae is an unusual subject for this Journal, and is of limited interest, but it was included in the July issue because published identifications of these wood-damaging beetles are urgently required in

forest entomology, and there would have been a delay of some two years before they would have appeared in a U.K. journal. Papers on fishery research subjects have also been published during the year, and the scope of the Journal has widened beyond agriculture in its widest sense, but its title is so well known that a change of name to include agricultural, veterinary, forestry, fishery, and testse research would be so drastic that the continuity would be broken in abstract journals and library classifications. This question of a change of name has been discussed several times in committees, but it has been decided to retain the present title because of the confusion in references which would result from a complete change of title, and the clumsiness of an expansion of the present title.

299. The number of books received for review continues to increase, and in the 1957 issues 35 reviews were published. Many of these are merely brief notices of books or pamphlets which are likely to be of interest to readers, while others give some details of the contents of the book and its appeal to farmers, field officers and research workers.

EAST AFRICAN PLANT QUARANTINE STATION

F. M. L. Sheffield and P. J. Dickinson

Staff and Buildings

300. There has been no change in staff or buildings during the period under review. While Dr. F. M. L. Sheffield was absent on leave Dr. H. H. Storey took over the pathological supervision of the station.

201. During her leave in the United Kingdom, Dr. Sheffield was able to discuss with the authorities in charge of plant protection and quarantine measures some of the problems they are facing, both when they allow the import of vegetative plant material, and when they issue certificates of export for such material. She visited South Africa and was able to discuss with the authorities there the measures they are taking to prevent the importation of pests and diseases, and also to prevent their spread within the Union. She was also able to visit the new Quarantine Station being erected at Stellenbosch.

Importations and Releases

302. The station is now working to the full capacity of the glasshouse space. A total of 117 varieties of various species were imported into quarantine during this period.

Food Crops

303. The Director of E.A.A.F.R.O. continued to import sugar-cane varieties on behalf of the three East African Territories, and wishes to express his gratitude to the Directors of all the Organizations who so willingly sent cuttings on request. Two rhyzome-forming varieties of *Cynodon dactylon* were also imported by E.A.A.F.R.O. at the request of Dr. H. C. Pereira.

Sugar Cane

304. The following 19 varieties of sugar cane were received into the Quarantine Station during the period 1st July, 1956, to December, 1957, and are now being held in closed quarantine.

Supplied by Experimental Station, South African Sugar Association, Mt. Edgecombe, Natal, South Africa

B.42231	CP.44/101	N.50/123
B.47419	N.10	N.50/211
CP.29/116	N.50/93	POJ.2940

Supplied by the Sugar Cane Breeding Institute, Coimbatore, India

Co.467	Co.680	Co.684

Supplied by the Mauritius Sugar Industry Research Institute, Reduit, Mauritius

B.3337	E.1/37	M.31/45
Co.779	H.37/1933	M.147/44
D.109		

305. Below are listed 20 varieties of sugar cane which were released from closed quarantine at Muguga. Three setts from each variety were heat-treated against Ratoon-stunting disease and are now established on the terraces at this station. This is part of the collection of new varieties started on the station with its inception at Muguga. All the remaining setts were sent to the Department of Agriculture Research Station, Kawanda, Kampala, Uganda, where they receive heat therapy before being planted out to multiply whilst in open quarantine for a further year. The varieties are:—

Ajax	CP.29/291	NCo.376
Comus	CP.29/305	NCo.382
Co.356	CP.34/39	Pindar
Co.464	CP.36/111	Q.47
Co.622	Eros	Q.50
Co.678		Q.56
Co.775		Q.57

Setts of the variety Comus were also sent to Mt. Edgecombe, where, although delayed for about two months in transit have been successfully established.

306. *Cynodon dactylon.* Cuttings of two varieties of *Cynodon dactylon* var. Nyasaland and Fort Jameson were imported at the request of Dr. H. C. Pereira, as being rhyzome-forming strains which may be useful in the badly eroded areas of East Africa. These have now been released to Mr. Ledger for further bulking up prior to trial.

307. *Maize.* At the request of the Director of Agriculture, Tanganyika Territory, five varieties of short-term maize were imported from the Maize Specialist, Pusa, Bihar, India, and are now being grown on. These are being quarantined because of the danger of seed-borne *Sclerospora,* as yet unknown in East Africa.

308. *Shallots.* A short day variety of shallot is being quarantined at the request of Director of Agriculture, Kenya, and was received from Ghana. These were received in such poor condition that it is doubtful if they will survive.

309. *Conifers.* At the request of the Kenya Forestry Department grafting material of elite trees of *Pinus radiata* were received from the Forestry and Timber Bureau, Canberra, Australia. Of 17 stems received eight have been established and are now held in quarantine for observation.

310. *Agathis.* Four seedlings of *Agathis labillardieri* were recently received from the Department of Forestry, Lea Territory

The initial letter prefixing the varietal number refers to the country of origin: B—Barbados; Co—Coimbatore, India; CP—Canal Point, Florida; H—Honolulu, Hawaii; M—Mauritius; NCo—raised in Natal from Coimbatore seed; POJ—Proefstation Oest Java; N—Natal, South Africa; Q—Queensland; D—British Guiana; E—Egypt; and the named varieties from Australia.

of Papua and New Guinea in the hope that it may be possible to establish this tree in East Africa, as previous trials with seed have been successful.

311. *Ornamentals.* The ornamentals we expect to receive into quarantine most frequently are *Begonia, Dahlia* and *Chrysanthemum.* These are often symptomless carriers of spotted Wilt Virus, and also of other viruses whose potential danger to East Africa is not fully understood.

312. *Chrysanthemums.* The second consignment of chrysanthemums which included the following varieties:—

Balcombe Perfection	Monty Strathen
Balcombe Yellow	Orange Hawk
Cotswold Flame	New Princess
Delightful	Sheila Rose
Florence Horwood	Tosca
Geoff Duke	Valetta
Late Delight	Velvet Gown
Mayford Crimson	

were all destroyed as carrying one or other of the many chrysanthemum viruses. A further consignment of some 26 varieties was received in April, 1957, of which some 19 have already been destroyed; some because of virus infection, and the remainder because of heavy leaf eelworm infestation.

313. *Dahlia.* A consignment of *Dahlias* received in July, 1956, was found to be infected with Tomato Spotted Wilt Virus and the whole consignment was destroyed. A further consignment of some 37 varieties was received from Holland in May, 1957, and is still in quarantine. To date, a few plants have been destroyed due to Dahlia mosaic and some have been released.

314. *Begonia.* One consignment of Fiberous Rooted Begonia was received for the Nairobi Parks Department, but they were so heavily infected with Root Knot eelworm that few plants survived. The whole consignment was destroyed due to this heavy infection which could not be eliminated.

315. *Insect Pests.* During the period under review two insect pests were found on plants in quarantine, both of which were unrecorded in Kenya: Sugar Cane Scale Insect (*Pulvinaria*

elongate, Newst.) and *Cynodon dactylon* mealy bug (Trionymus spp.). Both these pests were eradicated before the plants were released.

Experimental Work

316. *Sugar Cane.* Following on last year's work on the rooting of cuttings after hot water treatment a replicated trial was laid down with a variety supposed to be susceptible to hot water treatment. The results of this showed that with hot water treatment carried out under laboratory conditions the rooting of the cuttings was not affected in the numbers that grew, but the number of roots produced by each cutting was considerably increased. The vigour and size of these roots, however, was drastically reduced. This factor might be the cause of failures under field conditions.

317. The importation of certain Australian varieties resulted in poor growth of some canes, some varieties having as many as 18 nodes in as many inches. It was thought that this may be due to variance in day length of East Africa in comparison with the part of Australia where sugar cane was grown.

318. An experiment was laid down with two of these varieties, half the plants being given an increased day length to correspond with that of Australia, and the remainder received the day length of East Africa. This trial was run for six months but gave a negative result.

319. It has since been learnt that the South African Sugar Association Experimental Station at Mt. Edgecombe encountered the same shortness of cane in the Australian varieties when grown there, which is approximately the same latitude as the Australian sugar cane area.

Inter-African Phyto-Sanitary Commission

320. With the inception of I.A.P.S.C. considerable secretarial work has been necessary, together with the complete redrafting of the Schedule of Plants for the Standing Technical Committee on Plant Import and Export of East Africa. This schedule has now been circulated to all members as a draft, and on correction will be published as a card index for all concerned in the import and export of plants.

ATTACHED COLONIAL DEVELOPMENT AND WELFARE SCHEMES

THE EAST AFRICAN CEREAL PEST SURVEY

I. W. B. Nye

321. This two-year survey commenced in March, 1956, with three main objectives:—

(*a*) To determine the distribution of the various species of insect pests which attack maize, sorghum, millet, rice and sugar cane.

(*b*) To find out whether wild and cultivated host grasses (which may be used for contour banking or pasture) are important in carrying the pests from crop to crop during the dry season.

(*c*) To sort out the external morphology of the larvae of the various species so that they can be named in their immature stages when they are actually damaging the crop.

322. All the main agricultural areas have now been covered either by a personal visit or by material sent in from the agricultural departments, and the distribution of the major pests has been determined.

(*a*) *Atherigona indica infuscata* van Emden, the Central Shoot Fly of Sorghum, is universally distributed wherever this crop is cultivated and its host, the wild sorghums, grow.

(*b*) *Busseola fusca* (Fuller), the Maize Stalk Borer, is the most widespread and devastating species and occurs in all maize- and sorghum-growing areas over 2,000 feet. Fortunately it has a well-defined life cycle in relation to the onset of rains, and outbreaks can be controlled by insecticides.

(*c*) *Sesamia calamistis* Hampson, the Pink Stalk Borer, is widely distributed from sea level to at least 7,000 feet, and contributes to damage in maize, sorghum, finger millet and rice in most areas, but is normally outnumbered by one of the other species.

(*d*) *Chilo zonellus* (Swinhoe) occurs from sea level up to 5,000 feet, and is the second most damaging species. It is smaller in size than *Busseola* and appears to be less voracious and damaging to the plant. Its life cycle is not so definite in relation to the season, and it is accordingly more difficult to control by insecticides.

(*e*) *Chilotraea argyrolepia* (Hampson), the Lowland Stalk Borer, commonly attacks maize and sorghum in the coastal areas up to 2,000 feet.

(*f*) *Rhinaphe vectiferella* (Rag.) = *Ampycodes pallidicosta* (Hampson) = *Maliarpha separatella* (Rag.) is becoming an important stalk borer pest of rice round Lake Nyassa, Lake Victoria and on the Mwea/Tebere irrigation scheme in Kenya.

(*g*) *Contarinia sorghicola* (Coq.), the Sorghum Midge, whose larvae eat the developing seeds of sorghum heads has been found mainly in Sukumaland and around Lake Rudolf but is also present to a minor degree in Uganda.

(*h*) *Heliothis armigera* (Hb.) attacks sorghum heads and maize silks as well as cotton bolls. It has recently been shown that the American Boll Worm is a distinct species confined to North America. A special study is at present being made of the species occurring in East Africa.

(*i*) Other seed feeders are of importance not only for the damage which reduces the yield of the cereals themselves, but also for their interrelationship with other crops, in particular cotton which is often grown in close association with cereals; e.g. many of the sucking bugs including *Lygus* spp., *Dysdercus* spp. (Cotton Stainer), and *Calidea* spp. all feed on developing sorghum heads as well as on cotton, and migrate from one to the other.

323. In general in Kenya, Tanganyika and the drier areas of Uganda the wild host grasses do not appear to play a very important part in carrying on the infestation, but in the wet areas of Uganda, having lush grass growth, this is not the case, and all the main pests have been found commonly in wild hosts.

324. The immature stages of these pests which have been obtained from all areas are now being studied, and detailed diagrams of their structure are being prepared.

PLANT NEMATOLOGY

A. G. Whitehead

(*Colonial Research Fellow attached to E.A.A.F.R.O.*)

325. During the first year of a survey of the attacks of parasitic nematodes (eelworms) in East African crop-plants, field studies have been carried out in the Southern Highlands, Northern, Tanga and Lake Provinces of Tanganyika; in the Kigeze, Mubende, Toro, Bunyoro, West Nile and Gulu districts of Uganda and in the Nakuru, Naivasha, Kiambu, Ravine, Nandi, Trans Nzoia, Uasin Gishu, Baringo and Kericho districts and Coast Province of Kenya. As a result of detailed population and taxonomic studies on soil and root samples collected in these areas 22 genera of known and suspected parasitic nematodes have been found and are as follows: *Anguina* Scopoi, 1777 (seed-gall nematodes), *Aphelenchoides* Fischer, 1894 *Aphelenchus* Bastian, 1865, *Criconema* Hofmanner & Menzel, 1914 (Ring nematodes), *Criconemoides* Taylor, 1936 (Ring nematodes), *Ditylenchus* Filipjev, 1934, *Helicotylenchus* Steiner, 1945 (Steiner's spiral nematodes), *Hemicycliophora* de Man, 1921 (Sheath nematodes), *Hoplolaimus* von Daday, 1905 (Lance nematodes), *Longidorus* Micoletzky, 1922, *Meloidogyne* Goeldi, 1887 (Root-Knot nematodes), *Metaphelenchus* Steiner, 1943, *Paraphelenchus* (Micoletzky, 1922) Micoletzky, 1925, *Paratylenchus* Micoletzky, 1922 (Pin Nematodes), *Pratylenchus* Filipjev, 1934 (Meadow or Root-Lesion nematodes), *Rotylenchus* Filipjev, 1934 (Spiral nematodes), *Rotylenchulus* Lindford & *Oliveira,* 1940 (Reniform nematodes), *Trichodorus* Cobb, 1913 (Stubby root nematodes), *Tylenchorhynchus* Cobb, 1913, *Tylenchulus* Cobb, 1913 (Citrus nematodes), *Tylenchus* Bastian, 1865, *Xiphinema* Cobb, 1913 (Dagger nematodes), and of these all except *Meloidogyne* and *Ditylenchus* are new records for East Africa.

326. Over 80 per cent of East African crop plants are attacked by nematodes, including nearly all the major crops. Heavy nematode attack is generally associated with poor growth and unhealthiness with consequent loss of yield. The nematode attacks of main economic significance are those affecting bananas (widespread attacks of *Pratylenchus* and *Meloidogyne*), beans (widespread attacks of *Meloidogyne* spp. and localized attacks of *Pratylenchus* spp. and *Rotylenchus* spp.), cotton (localized attacks of *Meloidogyne* spp. in Uganda), clovers and most legumes (clovers

heavily attacked in Trans Nzoia, by *Meloidogyne* spp. the latter heavily attacked by *Meloidogyne* spp. all over East Africa), arabica coffee (heavy attacks of *Meloidogyne* spp. in Tanga and Northern Provinces and *Rotylenchus* sp. in Rungwe District, Southern Highlands Province, Tanganyika), maize (localized attacks of *Meloidogyne, Pratylenchus* and *Rotylenchus*), pineapple (heavy attacks of *Meloidogyne* spp. in Kenya and *Pratylenchus* in Tanga Province, Tanganyika), potatoes (widespread attacks of *Meloidogyne* spp.), pyrethrum (widespread and heavy attacks of *Meloidogyne* spp. and localized attacks of *Pratylenchus* spp. and *Aphelenchoides ritzema-bosi* (Schwartz) Steiner, "leaf-eelworm"), nursery tea (widespread attacks of *Meloidogyne* spp.), tobacco (widespread attacks of *Meloidogyne* in all main tobacco areas), and tomatoes (widespread attacks of *Meloidogyne* spp., localized light attacks of *Pratylenchus* spp.).

327. In preliminary pathogenicity tests *Meloidogyne* spp. were found to reduce the growth and vigour of potatoes, tomatoes and celery, as did *Pratylenchus* sp. on dwarf beans. On pyrethrum, the leaf nematode *Aphelenchoides ritzema-bosi* produced necrosis of leaf initials and retarded flowering, under high atmospheric humidity.

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